National Park Service
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Natural Resource Stewardship and Science

Natural Resource Conditions at Capitol Reef National Park

Findings & Management Considerations for Selected Resources

Natural Resource Report NPS/NCPN/NRR—2022/2406



ON THE COVER

Top: Scenic view from top of the Burr Trail switchbacks. Middle: Milky Way in CARE's night sky (left). Desert bighorn sheep ram (center). Maguire daisy (right). Bottom: Ackland Spring West (left). Mexican spotted owl (top right). Citizen scientists gathering dragonflies for mercury study (bottom right).

Image Credits: NPS / SHAUNA COTRELL (Burr Trail view), Milky Way (NPS / PHIL SISTO), © RANDYL NIELSON (ram), © MICHELLE DELA-CRUZ (daisy), NPS CARE (spring), NPS / SHAUNA COTRELL (owl), Citizen scientists (NPS Air Resources Division).

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Natural Resource Report NPS/NCPN/NRR—2022/2406

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Executive Summary

Capitol Reef National Park (CARE) encompasses approximately 381 mi^2 (98,711 ha) in southcentral Utah, and over 70% is managed for its rugged and remote wilderness value. It's known for its spectacular display of geologic features, including the Waterpocket Fold—an extensive, upthrusted sandstone geologic feature that is the longest exposed monocline in North America. CARE contains high plant diversity and has a large concentration of locally rare and endemic plants, representing about 18% of the park's total number of plant species. The Fremont River, perennial creeks, and springs, seeps, and tinajas are valued sources of water in the high desert environment of the Colorado Plateau, providing critical habitat for migrating and breeding birds, invertebrates, and other wildlife. At least 58 mammals, including desert bighorn sheep (*Ovis canadensis nelsoni*), have been confirmed at the park, and three native fishes are species of special conservation status in Utah.

The National Park Service Natural Resource Condition Assessment Program (NRCA) selected CARE to pilot its new NRCA project series. These projects evaluate the best available science to provide park managers with reliable, actionable natural resource condition information.

CARE managers selected 11 focal study resources for their NRCA. To help us understand what is causing change in resource conditions, we selected a subset of drivers and stressors known or suspected of influencing the park's focal resources. Here are some highlights.

What is causing change in resource conditions?

- It's expected that day and nighttime visibility (air quality) will improve because the largest coal-fired power plant in the Western U.S., south of the park, was decommissioned in 2019.
- Emissions from oil and gas development are not contributing to nitrogen deposition and ozone formation to a significant extent at the park.
- It's presumed that the origin of mercury in the park is largely from atmospheric deposition, and high levels of mercury are found in dragonfly larvae and fish sampled in the park.
- Historic livestock grazing impacts are reduced through the implementation of the Livestock Grazing and Trailing Management Plan, and grasslands/shrublands conditions have improved.
- The highest park visitation was 1,227,627 visitors in 2018. This is a little over a 121% increase from 2007, when the number of visitors steadily rose every year except for 2013.
- All climate models project warmer temperatures and, increasing landscape aridity, even though 80% of the models project some increase in precipitation.

What are the resource conditions?

Of the 11 focal study resources, adequate data were available to evaluate the current conditions and trends for five via condition assessments. A summary of the condition ratings by indicator is presented in Table ES-1, and some highlights from the five condition assessments follow.

Table ES-1. Summary of CARE's natural resource condition assessment indicators of condition ratings.

Focal Resource	Indicator of Condition	Condition Rating
Night Sky [1]	Illuminance	Good/Fair
	Luminance	Good
	Anthropogenic Light Pollution	Good
	Sky Quality	Good
Air Quality [1]	Visibility	Fair
	Ozone	Fair
Pinyon-Juniper Woodlands	Tree Density	Good
	Crown Cover Increase	Good/Fair
	Obligate Songbirds	Good
	Age-Class Distribution	Good
Grasslands/ Shrublands [2]	Soil and Site Stability (Sandy 3 & Hartnet)	Fair/Poor
	Soil and Site Stability (Rock Springs & Cathedral)	Good
	Hydrologic Function (Sandy 3 & Hartnet)	Fair/Poor
	Hydrologic Function (Rock Springs & Cathedral)	Good
	Biotic Integrity (Sandy 3 & Hartnet)	Fair/Poor
	Biotic Integrity (Rock Springs & Cathedral)	Good
	Nitrogen wet deposition (Park-wide)	Fair
Songbirds	Community Composition	Good/Fair
Fishes [3]	Biological Community (Fremont River)	Fair
	Habitat Quality (Fremont River)	Good/Fair
	Water Quality (Fremont River, Pleasant, Oak, Sulphur, & Halls creeks)	Good/Fair
	Contaminants (Fremont River, Pleasant & Sulphur creeks)	Fair/Poor

[1] Night sky and air quality were reported in the same evaluation.

[2] Condition ratings for the grasslands/shrublands were grouped by livestock grazing allotments.

[3] Condition ratings for fishes were grouped by river or creek(s), depending on data availability.

Night Sky and Air Quality

- The night sky is one of the darkest in all national parks throughout the contiguous U.S.
- Night sky data collection and lighting can be even further improved by focusing key monitoring locations, updating monitoring equipment, and retrofitting park lighting, such as the amphitheater lamps.

Pinyon-Juniper Woodlands

- There is little evidence of the park's pinyon-juniper woodlands becoming denser quickly.
- Fire risk is low due to the current lack of fuels, topography, and folded terrain.

Grasslands/Shrublands

- Monitoring has occurred in four grazing allotments, two of which have been retired for over 20 years and are in good condition and improving.

Songbirds

- Nearly all expected songbirds are present, but state- and Northern Colorado Plateau-level trends indicate some possible declines (can't extrapolate to park).
- Relationships between bird density and water deficit differed by species and habitat, with positive and negative results depending on habitat specialization.

Fishes

- Four native fishes and eight non-natives are present in the Fremont River, but the native roundtail chub is extirpated.
- 15% of samples exceeded Utah's water quality standards for temperature, and all samples met standards for dissolved oxygen in the Fremont River, Pleasant, Oak, Sulphur, and Halls creeks.
- Seven contaminants of emerging concern were identified in the Fremont River and Pleasant Creek, with mercury possibly affecting fish health at both locations.

What is known about resources with limited data?

For the remaining six focal study resources with limited data, gap analyses were developed, highlighting the status of knowledge and useful indicators, data, and studies for future investigation. Here are some highlights.

Soundscape

- The predicted sound level impact was lowest in the primitive and semi-primitive management zones, and vehicle counts from May to August substantially rose after 2009.

Springs, Seeps, & Tinajas

- There could be as many as 170 springs and seeps in the park, and 35% of the park has the potential to support tinajas.

Riparian

- Fremont River groundwater depth is adequate to maintain riparian trees and possibly seedlings.
- Pleasant Creek's riparian was in Proper Functioning Condition (PFC), and Oak Creek's riparian was in non-functioning condition but improving.

Rare Plants

- 57% of the 426 rare plant sites across the 26 target species were in the park.
- CARE's rare plant sites show less disturbance than areas outside the park.

Mexican Spotted Owl (MSO)

- Adults have been confirmed in all nine protected area centers (PACs) in the park, with potential for additional sites in the park to be eligible for PAC status.
- Young have been detected in eight of the nine PACs in the park.
- There's a lot of variability in monitoring results because of site inaccessibility.

Desert Bighorn Sheep (BHS)

- There is substantial habitat connectivity in the Kaiparowits, Escalante BHS management unit.
- Pneumonia transmission from domestic sheep and goats presents a challenge because maintaining healthy BHS populations depends on gene flow through connected habitat.

How can we bridge NRCA findings with management actions?

To link NRCA science to management activities, meetings were held with a team of scientists and park managers. The team reviewed the NRCA findings and discussed ideas about potential near-term and future actions managers can consider for the 11 natural resources and associated drivers and stressors evaluated in CARE's NRCA. Here is a subset of the discussion outcomes.

Night Sky, Air Quality, and Soundscape

- Evaluate scenic views and integrate monitoring for night sky, scenic views, and air quality.
- Evaluate effectiveness of quiet pavement options for managing noise along the Scenic Drive.
- Partner with agencies to inform adjacent developments about landscape-level impacts.

Water-based Resources

- Determine groundwater recharge areas and residence times associated with source aquifers for springs and seeps, and delineate tinajas quickly and accurately over large areas using LiDAR.
- Use PFC assessment to understand groundwater/surface water interactions.
- Identify streamflow needs and monitor contaminants, including mercury levels, for fish.

Vegetation Resources

- Partner with U.S. Forest Service to manage the natural processes of pinyon-juniper woodlands across jurisdictional boundaries.
- Refine management questions and goals for monitoring rare plants and partner with Tribes.
- Expand grasslands/shrublands monitoring to non-grazing areas and install weather stations.

Wildlife Resources

- Focus songbird monitoring to evaluate condition and trend at park-level.
- For MSO, implement a multi-park occupancy study to determine if U.S. Fish and Wildlife Service delisting goals are met.
- Focus management actions on the core areas of BHS habitat use.

Conclusion

CARE's NRCA captures the institutional knowledge of park managers and the expert opinions of scientists, linking drivers and stressors to resource conditions and management actions. The collaborative and integrated resource management actions identified in the NRCA position the park to begin its Resource Stewardship Strategy and "to refocus its long-term management and funding needs", especially as CARE's Resource Management and Science Division transitions with new staff and develops a strategy to manage the increased park visitation to minimize resource impacts.

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List of Acronyms

AIM: Assessment, Inventory, and Monitoring

ALR: All-sky Light Pollution Ratio

ARCH: Arches National Park

ARD: Air Resources Division

AUM: Animal Unit Month

BBS: Breeding Bird Survey

BHS: Bighorn Sheep

BLM: Bureau of Land Management

BRD: Biological Resources Division

CANY: Canyonlands National Park

CARE: Capitol Reef National Park

CCRP: Climate Change Response Program

CEC: Contaminants of Emerging Concern

dBA: A-weighted decibel (dB) values

DPSSR: Drivers, Pressures, Stressors, States, Responses

FCA: Focused Condition Assessment

FIA: Forest Inventory and Analysis

GRD: Geologic Resources Division

GLCA: Glen Canyon National Recreation Area

GCM: Global Circulation Model

GSENM: Grand Staircase-Escalante National Monument

IEP: Invasive Exotic Plant

IIRH: Interpreting Indicators of Rangeland Health

IMBD: International Migratory Bird Day

List of Acronyms (continued)

IMD:	Inventory & Monitoring Division
IPMT:	Invasive Plant Management Team
LGTMP:	Livestock Grazing and Trailing Management Plan
MACA:	Multivariate Adaptive Constructed Analog
MSO:	Mexican Spotted Owl
NAIP:	National Agriculture Imagery Program
NAS:	National Audubon Society
NCPN:	Northern Colorado Plateau Inventory & Monitoring Network
NDVI:	Normalized Difference Vegetation Index
NF:	National Forest
NOAA:	National Oceanic and Atmospheric Administration
NPS:	National Park Service
NRCA:	Natural Resource Condition Assessment
NRSS:	Natural Resource Stewardship and Science Directorate (NPS Washington support office)
NSNSD:	Natural Sounds and Night Skies Division
OHV:	Off-highway vehicle
PAC:	Protected Activity Center
PFC:	Proper Functioning Condition
PHDI:	Palmer Hydrological Drought Index
PIF:	Partners in Flight
RCP:	Representative Concentration Pathway
SDI:	Stand Density Index
SQM:	Sky Quality Meter
UDWQ:	Utah Division of Water Quality

List of Acronyms (continued)

UDWR: Utah Division of Wildlife Resources

USEPA: United States Environmental Protection Agency

USFS: United States Forest Service

USFWS: United States Fish and Wildlife Service

USGS: United States Geological Survey

USU: Utah State University

WRD: Water Resources Division

ZION: Zion National Park

Note: Acronyms were not included if all references were within the same page.

Glossary

Condition Assessment: A condition assessment reports on the *current condition* of one or more *indicators of condition* for a given resource. A resource topic is selected as a condition assessment when enough data are available to inform current condition of selected indicators, which are evaluated by using scientifically justifiable *condition rating statements*. What constitutes "enough" data is a professional judgement based on a review of all available data and discussion with park staff, subject matter experts, and researchers involved in collecting the applicable data. Condition is evaluated for each indicator using a 5-level rating system, ranging between good-fair-poor; if trend can be reported for an indicator, it is reported as improving, stable, deteriorating, or unknown/indeterminate.

Condition Rating Statements: These correspond to the five-level rating system developed for the indicators of condition. The five levels are good, good/fair, fair, fair/poor, and poor, with corresponding "stop light" colors. Condition ratings statements are developed at the indicator level for the combination of measures evaluated for each indicator. The statements must be logical and defensible based on the best available science.

Confidence Level: These correspond to a three-level rating system of low–medium–high described for the indicators of condition rating evaluation. These levels are based on the repeatability of evaluation findings and how confident the author is in the information used to evaluate condition.

Current Condition: This defines the status of condition for an indicator based on the accumulation of one or more measures. "Current" applies to the condition as it exists today, based on what has previously occurred, not on what is likely to occur. Something such as level of hazard or risk, which identifies the proposed or likelihood of what may occur due to the intrinsic characteristics of the resource, will not be used to report on current condition**.** In general, data collected within the last ten years can be used to determine current condition, although this will depend on the rate of change for a particular indicator and its corresponding measures.

Data Gap: A resource is listed as a data gap when information is lacking, or expertise is needed to adequately evaluate condition. One key difference between a data gap and a gap analysis is the level of information reported.

Driver: Ecosystem drivers are major (and most often) external influencers of change to natural systems, functioning across large areas or scales. Drivers are defined as "any relatively discrete events in space and time that disrupt ecosystem, community, or population structure and change resources, substrate, or the physical environment (White and Pickett 1985)." Drivers are most often beyond a manager's ability to influence or change.

Gap Analysis: A gap analysis is a summary of what is known about a given resource in addition to what information is lacking rather than reporting on an indicator of condition. These information gaps are summarized in a table of *proposed* indicators, measures, and reference criteria with the goal of providing a framework for a future study.

Indicator: An indicator is a descriptor of something useful to measure, but it is not the measure itself. Indicators should be specific, measurable, and sensitive to change. Status of current condition for a condition assessment is assigned at the indicator level. This is because resources are often more complex and nuanced than what is reflected in just a few measures. In a gap analysis, these are listed as *proposed* indicators with no condition assigned to them.

Measure: A measure is either qualitative or quantitative and provides specific information about the indicator. There can be one or more measure(s) for each indicator. Selected indicators and measures are often those that are commonly used by NPS staff in monitoring the status of a resource, as well as those that are well represented in the literature and can provide context when park-specific data are lacking. In a gap analysis, these will be listed as *proposed* measures.

Pressure: A pressure is a result of a driver that potentially affects a resource. An NRCA presents drivers and pressures as the fundamental forces that play important roles in regulating or altering ecological resource conditions in the park and does not differentiate between the two.

Reference Criteria: Reference criteria are pivot points, thresholds, or ranges based on peer-reviewed literature, state standards, known criteria, or some other justifiable source of information. Quantitative reference criteria are generally better than qualitative reference criteria, but when specific data are lacking, qualitative reference criteria are useful. Regardless of the type of reference criteria used, they must be justifiable. In a gap analysis, these will be listed as *proposed* reference criteria.

Response: Management implications and useful near-term actions/activities park managers can consider to protect, maintain, and/or restore important ecological resource conditions in parks.

State (Condition): The "health" or condition of the resource reported at the indicator level. Refer to the definition for Current Condition above.

Stressor: "Stressors can manifest as physical, chemical, or biological perturbations to a system that are either foreign to that system, or natural to the system, but occurring at an excessive or deficient level. Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. They act together with drivers on ecosystem attributes (Barrett et al. 1976)." When possible, stressors are selected as measures with which to evaluate current condition of an indicator.

Natural Resource Condition Assessment – Introduction

The National Park Service's (NPS) Natural Resource Condition Assessment (NRCA) Program evaluates natural resource conditions in park units and delivers the results to park staff, scientists, strategic planners, and the general public through reports and associated products. All NRCA efforts strive to report resource condition information that informs multiple levels of park stewardship activities. Stewardship activities may include partnerships, resource stewardship plans, park management plans, and may inform on-the-ground actions that park management can implement.

As part of the NRCA program, Natural Resource Condition Assessments (NRCAs) are one-year projects designed to provide efficient, yet defensible, "status of knowledge" information on drivers and stressors, current conditions, and critical data gaps for a limited number of important park ecological resources. NRCAs are intended to use the best available scientific data for park-selected focal resources, drivers, stressors, and manager questions or needs. This body of scientific information is synthesized, analyzed, and interpreted using appropriate study methods and techniques. A manager-scientist team of experts considers the overall reasonableness and defensibility of study findings, management implications associated with those findings, and useful responses that park managers may consider to further understand, maintain, and/or improve natural resource conditions.

Standard products from NRCA projects include a detailed project report and associated products. These may include species checklists, geospatial maps and data, presentations, and others. All reports and associated products are available via the NPS Datastore (https://irma.nps.gov/DataStore/).

Conceptual Framework for Assessing Resource Conditions and Influences

NRCA projects employ a Drivers, Pressures, Stressors, States, and Responses (DPSSR) conceptual framework (Figure I-1) similar to that used and advocated by others (Office of National Marine Sanctuaries 2020; Harwell et al. 2019). The DPSSR framework structures the content in an NRCA report and guides discussions of the anthropogenic and/or natural factors that "drive" ecosystem change. The effects of a driver or pressure (hereafter referred to as driver) may affect the current condition (or state) of a natural resource indicator as a positive or negative stressor. For stressors that are within the park's "span of control", a park management response may maintain, improve, or restore the natural resource indicator of condition to a desired state. For stressors that the park can't directly manage or influence, it's still helpful to understand potential impacts, especially when identifying realistic resource management goals.

It's important to note that an NRCA project does not report on all natural resources for a park. Instead, the NRCA Program or park managers may use the DPSSR framework to guide the evaluation of new natural resource conditions or to re-evaluate conditions in future NRCAs, especially as drivers or stressors change or as new information becomes available.

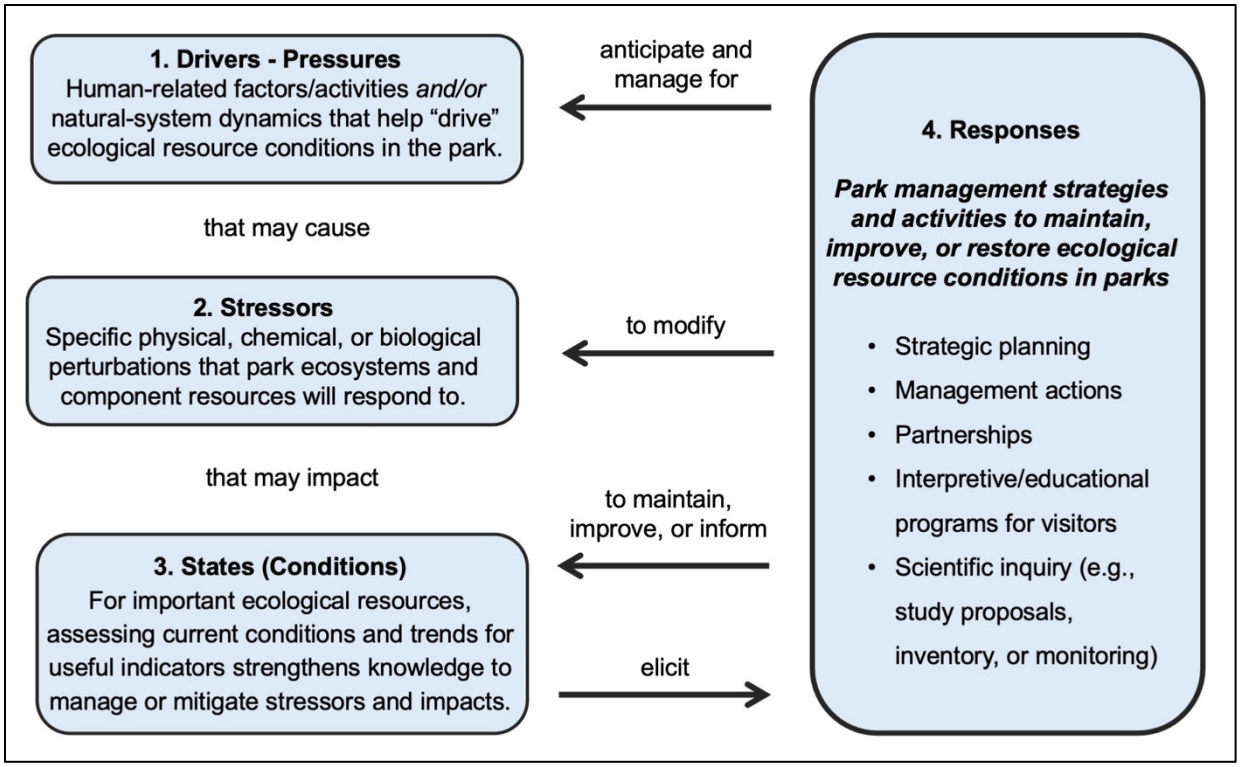


Figure I-1. The DPSSR conceptual framework is used to report drivers, stressors, states, and responses in NRCA studies (adapted from Harwell et al. (2019) and the Office of National Marine Sanctuaries (2020)).

NRCA Technical Report

Each NRCA projects are developed in five phases: project initiation, study plan scoping, study plan development, technical report development, and project finalization. During the initiation and study plan scoping phases, park managers select the subset of important focal natural resources that will be evaluated with respect to their conditions/states. Park managers also identify specific management questions and information needs they hope can be addressed in the NRCA study. During the study plan scoping and development phases, the focal resource drivers and stressors are identified and then reported in the technical report's Chapters 2 & 3. Management responses and considerations that help protect, maintain, and/or improve the focal natural resource conditions or to inform critical data gaps are reported in Chapter 4.

Focal Resources and Drivers & Stressors Summary for CARE's NRCA

Capitol Reef National Park (CARE) managers selected 11 focal resources for the park's NRCA. The primary drivers and stressors influencing the conditions of those resources are listed in Table I-1, using the Conservation Measures Partnership (2016) *Classification of Conservation Actions and Threats* categories and terminology. The classification defines a common nomenclature to support collaboration among conservationists and consistency across NRCA reports.

Table I-1. The primary drivers-pressures and stressors influencing the conditions (states) of CARE's focal resources. The categories are from the Conservation Measures Partnership (2016) classification.

Drivers-Pressures ***Fundamental Forces to Consider***	**Stressors** ***Potential Influences to Consider***
Agriculture	Livestock farming & ranching (upstream)
	Legislated livestock grazing & trailing (in park)
Residential & Commercial Development	Noise & light pollution
Energy Production & Mining	Power-plant air-borne pollution
	Resource exploration & extraction
Biological Resource Use	Pinyon-juniper removal
	Bighorn sheep population control & genetic isolation
Transportation	Roads and highways (Highway 24)
Human Intrusions & Disturbance	Illegal off-highway vehicles
	Illegal hunting & trespass
	Hiking, canyoneering, backpacking, & climbing
	Noise & light pollution
Invasive & Problematic Species, Pathogens, & Genes	Problematic animals, insects, diseases, & plants
Natural Systems Modification	Altered hydrology (water use, diversions, rights)
	Water contaminants
	Fire
Climate Change	Changes in temperature & precipitation regimes (including drought)

Chapter 1. Introduction to Park Setting and Resources

Capitol Reef National Park (CARE, park) is one of 63 national parks included in a system of 423 national park units. It was congressionally legislated as a national monument in 1937, then as a national park in 1971 to preserve the "striking geologic landscapes within the Colorado Plateau, including the Waterpocket Fold, Cathedral Valley, and their associated ecosystems, as well as magnificent scenery, scientific value, wilderness character, and rich human history" (CARE Presidential Proclamation (August 2, 1937, No. 2246) and Legislative Act (December 18, 1971, Public Law 92-207) as cited in NPS (2018a)). CARE is administered by the National Park Service (NPS), which is one of nine bureaus and offices of the Department of Interior that manages America's vast natural and cultural resources for the enjoyment and use of future generations.

1.1. Location

CARE is in the Colorado Plateau region of south-central Utah, approximately 351 km (218 mi) southeast of Salt Lake City, Utah (Figure 1.1-1). It encompasses an area of approximately 381 mi^2 (~98,000 ha), and over 70% is managed for its rugged and remote wilderness value (NPS 2018a). CARE extends approximately 97 km (60 mi) from north to south and is on average 9.7 km (6 mi) wide, containing the Waterpocket Fold—an extensive, upthrusted sandstone geologic feature that extends 160 km (100 mi) and is the longest exposed monocline in North America (Graham 2006).



A scenic vista overlooking the Waterpocket Fold from the Strike Valley Overlook. Image Credit: NPS.

Most of the region surrounding CARE is comprised of lands managed by the U.S. Forest Service (USFS) and the Bureau of Land Management (BLM). CARE shares its boundary with the Fishlake and Dixie National Forests (NF) to the west, Glen Canyon National Recreation Area (GLCA) to the south, BLM holdings on the park's eastern and northern boundaries, and the Grand Staircase-Escalante National Monument (GSENM) to the southwest. GLCA, BLM, and USFS lands allow for multiple use activities, such as resource extraction or livestock grazing, but protect the land from major development (USGS 2018; GreenInfo Network 2021).

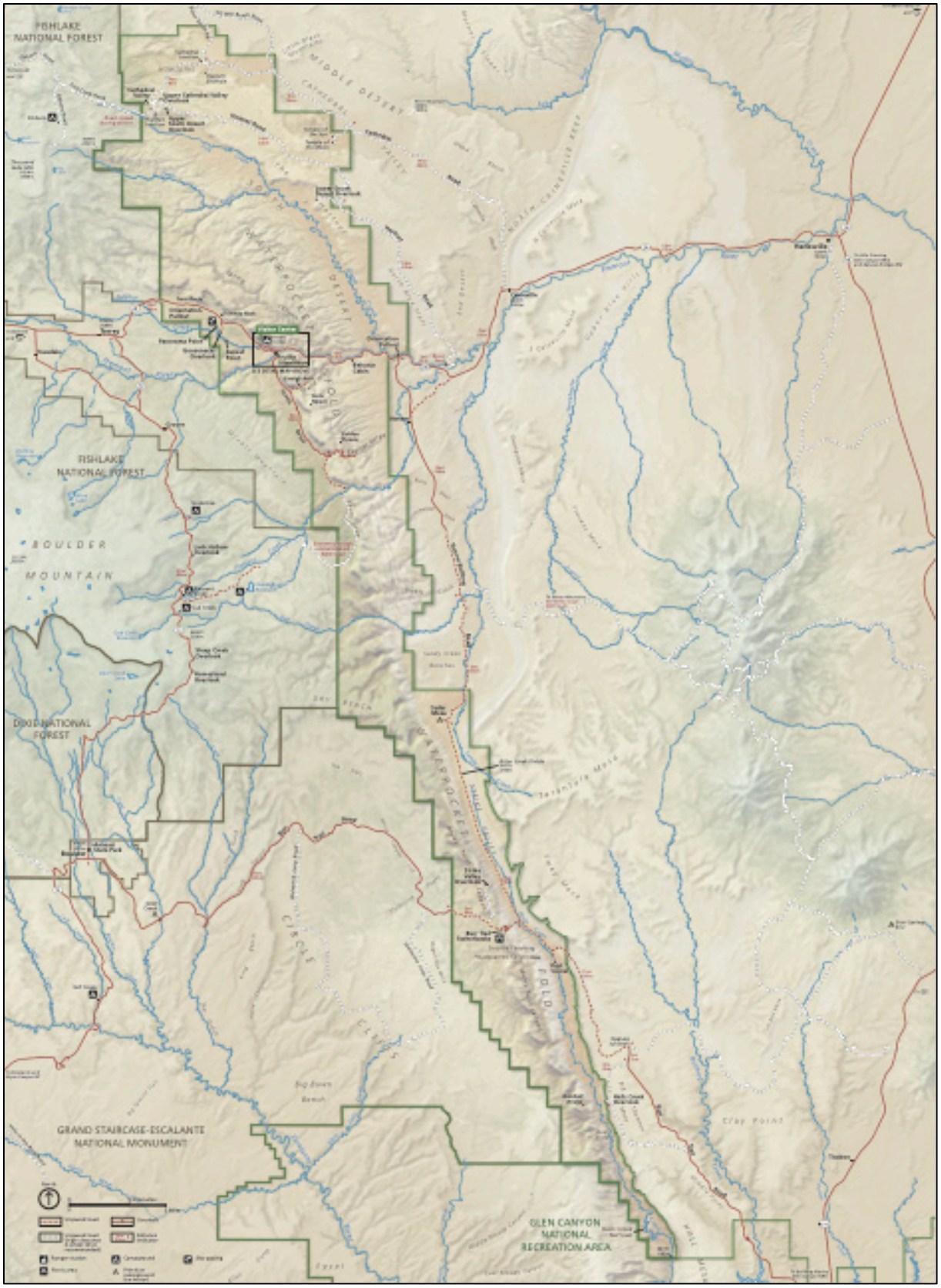


Figure 1.1-1. NPS map of CARE and surrounding region. Figure Credit: NPS / Harpers Ferry Center.

1.2. Setting and Resources

The Colorado Plateau Physiographic Province encompasses an area of 386,242 km^2 (240,000 mi^2) and is known for its colorful and relatively un-deformed geology, as characterized by its relatively flat-lying sedimentary rock, and high desert arid climate that has formed the region's present-day topography and soils. The province is divided into six sub-provinces, and the elevated topography of the High Plateaus is to the west of the park, and Canyonlands—an area known for its spectacular displays of sandstone and shale features (Banner 1992)—is to the east. CARE ranges in elevation from its lowest point at 1,183 m (3,880 ft.) to its highest point at 2,731 m (8,960 ft) from south to north. Its rugged and remote landscape is carved by wind and water, offering spectacular vistas of colorful geologic features, exceptional dark night skies, and diverse habitats.



A view of CARE's colorful landscape along the Scenic Drive. Image Credit: NPS.

1.2.1. The Waterpocket Fold

The Waterpocket Fold is a monocline, which is a wavelike contortion in rock strata that gently dips into steplike bends. These are formed in stable interiors of continents where rocks only mildly warp, as opposed to complex folds that are formed in mountain belts (Hamblin and Christiansen 2004). CARE's geodiversity spans 275 million years and includes large-scale folds (i.e., Waterpocket), faults, and fractures, as well as igneous features like sills and dikes, which are common signs of

ancient magma activity (Graham 2006; Hamblin and Christiansen 2004). The park's namesake, Capitol Reef, came from early visitors who thought the rounded rock domes resembled Washington, D.C. rotundas (hence Capitol), and reef, which referred to any rocky barrier to travel, such as the rugged Waterpocket Fold that extends along CARE's interior (Graham 2006).

1.2.2. High Desert Environment

The park's high desert environment is influenced by the climate and the rivers and creeks that flow through it, and in some instances, deeply erode the bedrock into meanders or "goosenecks." The perennial waters in CARE include the Fremont River and Polk, Sulphur, Pleasant, Oak, and Halls creeks. The steep, narrow canyons within the Waterpocket Fold and along the Fremont River and its tributaries occasionally respond to intense rainfall as flash floods, which is typical in an arid/semi-arid climate, affecting stream channel morphology, erosion, and deposition (Graham 2006). Many small springs, seeps, and tinajas are scattered throughout the park, and though most tinajas are ephemeral, these water sources are critical resources for wildlife in an arid environment.



Fall colors along Sulphur Creek. Image Credit: NPS.

CARE is characterized by hot summers, cold winters, and low humidity. Temperatures range from a mean January low of 16.5°F (-8.6°C) to a mean July high of 89.1°F (31.7°C; Witwicki 2020). Mean annual precipitation is 239 mm (9.4 in), which tends to be evenly distributed throughout the year, with the exception that June is consistently the driest month, and spring and late summer can be wetter (Witwicki 2020). Pacific fronts bring precipitation in fall through spring, including some snow in winter. Much of the precipitation in July through September occurs as thunderstorms attributable to the North American Monsoon (hereafter, "monsoon"), but the amount of precipitation from this source can vary greatly from year to year because CARE is situated at the monsoon's northernmost distribution (Schwinning et al. 2008).

1.2.3. Flora & Fauna

Coles et al. (2009) mapped 98,650 ha (243,768 ac) of vegetated (91%) and unvegetated (9%) classes within CARE's boundary, with an overall accuracy of 77%. The unvegetated classes include perennial streams (25 ha/62 ac), bare talus/slides (1,146 ha/2,832 ac), sandstone (6,986 ha/17,263 ac), and orchards (14 ha/35 ac). The vegetation map class with the largest area in CARE and the surrounding region was the Pinyon-Juniper/Mesic Shrubs Woodland Complex (27,446 ha/67,821 ac), accounting for 27.8% of the park's area (Coles et al. 2009).

The distribution of vegetation is controlled by the geology, soils, elevation, and aspect, with the south- and north-facing eroded slopes in the Waterpocket Fold supporting very different vegetation communities and one of the largest concentrations of rare and endemic plants in the NPS (Coles et al. 2009). According to CARE's annotated checklist of plants and subsequent updates, there are 28 locally endemic and 110 regionally endemic taxa in the park (Fertig 2009; Fertig et al. 2012). Locally endemic species are found in very limited areas, while regionally endemic species are more widespread on the Colorado Plateau (Fertig 2009). Rare and endemic species represent about 18% of the park's total number of species (Fertig 2009).

The park's ecological zones, including the water-dependent environments—riparian corridors, rivers and creeks, springs, seeps, and tinajas—are especially important to wildlife in an arid/semi-arid climate. These areas provide important habitat for a suite of terrestrial and aquatic invertebrates, amphibians, breeding and migratory birds, and a variety of mammals. The National Audubon Society designated the Fremont River riparian corridor in CARE as an Important Bird Area because the plant community along the river provides critical habitat for migrating and breeding birds. CARE also supports habitat for the federally threatened Mexican spotted owl (*Strix occidentalis lucida*).

Fifty-eight mammals have been documented in the park, ranging in size from rodents and bats to large ungulates and predators, including desert bighorn sheep (*Ovis canadensis nelsoni*) and mountain lion (*Puma concolor*) (NPSpecies 2021). Of the five native fishes that are present in CARE, three are species of special conservation status in Utah (UDNR 2006).

Chapter 2. Drivers and Stressors

Chapter 2 summarizes select primary driving forces (drivers) and the physical, chemical, and biological disturbances (stressors) of the selected focal resources. For streamlining purposes, drivers and pressures are not differentiated throughout the report, and when stressor-related data are available (e.g., non-native invasives, water contaminants), they are used as indicators of condition and/or measures to evaluate the states of park-selected focal natural resources in Chapter 3.



Fruita orchard in bloom. Image Credit: NPS / CHRIS ROUNDTREE.

2.1. Human History

CARE's rich cultural history dates to over 12,000 years ago, and while no artifacts have been found in the park, it's believed that Paleoindians, who arrived during the last Ice Age, migrated through the Waterpocket Fold (American Southwest Virtual Museum 2021).

The Fremont River served as a travel corridor, a place to hunt and gather, and a good resting or camping area for the Desert Archaic Indians who inhabited the region from about 8,000 to 1,600 years before present (Sucec 2006). The Fremont Culture and Ancestral Puebloans (from about 300 to ~1,300 Common Era) also used riparian corridors in this way, but incorporated farming of corn, squash, and other edible plants. More recently, Southern Paiutes and Utes were living in and around the park before Euro-American settlement, relying on riparian areas for hunting, gathering, and agriculture (Sucec 2006).

In arid landscapes like CARE, perennial springs and tinajas were also important to the survival of the region's original inhabitants, not only for the water itself, but because water attracted wild game (Sucec 2006). Finding springs in the desert was so important that Ancestral Hopi included their locations in petroglyphs (Sucec 2006).

Historically, the arrival of songbirds in spring and departure in autumn signaled a change in season, and the music of singing birds would have provided a backdrop to daily life during the spring and summer months for Indigenous peoples of the region. Grouse and other gamebirds were hunted by Indigenous peoples prior to Euro-American settlement, and feathers from some birds may have been used as decoration or in ceremonies (Sucec 2006). Several Hopi Clan names were inspired by birds, including the Bluebird Clan, the Eagle Clan, and the Killdeer Clan (Sucec 2006).

The former abundance and distribution of desert bighorn sheep (BHS) was recorded on the sandstone walls of the Waterpocket Fold by the Fremont Culture (Bellew et al. 1995). And in 1776, Fray Sivestre Velez de Escalante wrote "through here bighorn live in such abundance that their tracks are like those of great flocks of domestic sheep" (Bellew et al. 1995).

While there is no oral history of Indigenous peoples fishing in the park, bone fish hooks "of unknown provenience from the Pectol Collection suggest that some person of native ancestry was fishing in the vicinity, if not the park" (Sucec 2006). The Powell expedition reported many instances of fishing on a creek in what is now the Dixie NF, and there are also many records of abundant fish in the Fremont River from early Euro-Americans. Given the historical abundance of fish and the occurrence of cultural artifacts related to fishing found in the region, it's almost certain that fish were a part of the diet of Indigenous communities living in and around the park (Sucec 2006).

In addition to wildlife, many plants were used for food, medicine, ceremonies, decorations, baskets, and other materials (Sucec 2006). For example, some plants used by the Hopi include four-wing saltbush (*Atriplex canescens*), Mormon (Hopi) tea (*Ephedra viridis*), prickly pear cactus *(Opuntia* spp.), rabbitbrush (*Chrysothamnus naseousus*), greasewood (*Sarcobatus vermiculatus*), and sagebrush (*Artemisia* spp.), among others (Sucec 2006). In addition, pinyon-juniper woodlands have been a traditional location for Native American pine nut gathering (Noyes 2012), and since the early Holocene, have provided food, shelter, and raw materials (Janetski 1999).

With the arrival of pioneers and settlers from the Church of Jesus Christ of Latter-day Saints to the region in the 1800s, the first fruit and nut orchards were planted and tended in what is now the Fruita Rural Historic District along CARE's Fremont River and Sulphur Creek (White 1994; Crampton 1965). Today, orchard management is the responsibility of CARE staff, who maintain many heirloom varieties using heritage techniques, and conduct a comprehensive condition assessment of the orchard every five years (Rembelski and Maslan 2020).

Rembelski and Maslan (2020) report that there were 1,889 living trees in the Fruita orchards in 2020, with conditions focusing on apple, apricot, peach, pear, cherry, and plum, which account for a little over 95% of the total number of trees. Fifty-five fruit and nut varieties, and some unknowns, were

documented during the 2020 condition assessment. Forty-four percent of the trees were in good or excellent condition, and 43% and 12% were in fair or poor condition, respectively.

Orchard management is labor intensive because of pests, diseases, nutrient deficiencies, and structural defects that are common stressors, in addition to employing heritage techniques to maintain the historic integrity of maintenance and upkeep. Visitors to the park are encouraged to harvest fruit when ready, but as warmer and drier conditions increase and water availability becomes scarcer, orchard managers will be tasked with identifying management goals that are realistic and achievable, facing similar challenges as those discussed for the natural resources presented in this report.



According to Pollinator Partnership (2021), pollinators, such as this bee on a peach blossom, “are responsible for bringing us one out of every three bites of food.” Image Credit: NPS / SHAUNA COTRELL.

2.2. Visitor Use & Recreation

In 2018, CARE recorded its highest number of recreation visits at 1,227,627 since counting began in 1938 (NPS Stats 2021a), representing a 121% increase since 2007. Monthly visitation in 2018 was highest from April through October, with over 100,000 recreational visitors in each of those months; the highest number of visitors was 166,826 in September (It’s important to note that the park’s 2020 visitation was anomalously low, which is also when the COVID-19 outbreak occurred). Almost 5% of the total number of visitors in 2018 camped, with 0.33% of the total (i.e., 4,048 visitors) staying in the backcountry (NPS Stats 2021a).

In 2020, Utah ranked as the 4th highest state for NPS-related visitor spending nationwide (Cullinane and Koontz 2021). It is estimated that in 2020, $878 million was spent by the 11.1 million national park visitors in Utah. CARE accounted for almost 9% of the visitors in 2020 (~981,000), and an estimated $72.4 million was spent in the local gateway region surrounding CARE, which is a little over 8% of the state's total (Cullinane and Koontz 2021). The highest expenditures included services, such as lodging, gas, restaurants, and retail, representing a 62.3% regional spending increase since 2012 (Cullinane and Koontz 2021). However, the highest amount of spending increase of 257% and 265% occurred in 2018 and 2019, respectively, coinciding with the highest number of visitors to the park during both years.



Backpackers are encouraged to camp on durable surfaces, such as the slickrock shown in this photo, because it helps to reduce visitor impacts to CARE's resources. Image Credit: © UTAH VALLEY UNIVERSITY/JULIE OSTLER.

The high visitor use at CARE can negatively affect resources, especially given the fact that visitation rapidly increased with little time to develop and implement strategies minimizing resource impacts. Visitor use-related stressors on CARE's aquatic environment include swimming, hiking across streams, and illegal construction of rock dams to create swimming holes, which could inhibit fish movement and degrade habitat (NPS 2018a). Visitors may also contribute to stream pollution by applying insect repellent and sunscreen before wading or swimming. The natural acoustic environment is also affected by the higher number of vehicles and backcountry users, which may

negatively impact nesting or roosting Mexican spotted owls and other wildlife. The increased use of backcountry areas can also spread non-native invasive plant seeds, which are especially problematic as populations become established in the remote, rugged backcountry, making it difficult to access for control efforts.

2.3. Non-native Invasive Plants

Competition from non-native invasive plants is a stressor to CARE's vegetation communities, and over 120 non-native plant species have been reported for the park, representing about 14% of CARE's total plant species (Fertig 2009). The Northern Colorado Plateau Inventory & Monitoring Network (NCPN) conducts rapid monitoring for non-native invasive plants at CARE, focusing efforts along the major vectors (e.g., roads, trails, waterways) (Fahey and Perkins 2021). NCPN and CARE staffs developed a priority invasive exotic plant (IEP) list (2009–2019), identifying 29 species that are currently or potentially in the park (refer to Table 2-1 in Fahey and Perkins 2021). A four-year rotation of five routes, including Highway 24, Pleasant and Oak creeks cattle trails, the Scenic Drive, and Cathedral Valley Road, is searched.

The frequency of comparable IEP species increased along the Scenic Drive (2004) and Cathedral Valley (2005) in 2019, including tamarisk (*Tamarix* spp.) at both locations (Fahey and Perkins 2021). Russian olive (*Elaeagnus angustifolia*) was discovered for the first time along Cathedral Valley Road in 2019 (Fahey and Perkins 2021). CARE's efforts to manage IEP species include assistance from the NPS Invasive Plant Management Team (IPMT). In recent years, IPMT has removed Russian olive from Sulfur Creek and the Fremont River, and tamarisk from Ackland Springs. CARE staff or volunteers also periodically remove non-native invasive plants (Russian thistle (*Salsola tragus*), Halogeton (*Halogeton glomeratus*), horehound (*Marrubium vulgare*), bull thistle (*Cirsium vulgare*), blue mustard (*Chorispora tenella*), and others) in and around the Fruita Historic District (NPS, C. Livensperger, personal communication, 4 November 2021). Additional information about non-native invasive plants and their impact on CARE's natural resources is presented in the springs, seeps, & tinajas, riparian, grasslands/shrublands, rare plants, and songbirds evaluations.

2.4. Ranching & Livestock Management (Grazing & Trailing)

From the late 1800s through the mid-1990s, cattle and some sheep grazed much of what is now the park, and stock ponds, fences, and impoundments were built to support livestock grazing. Nineteen allotments were grazed in CARE when the park was established in 1971, but by 2000, only two allotments were actively grazed (Hartnet and Sandy 3), and in 2018, grazing on the Hartnet allotment was discontinued (NPS 2018b). Although CARE has only one active grazing allotment today, there are several livestock trails used to move cattle between winter and summer grounds, which are located outside of the park. The park's enabling legislation allows for the continued use of historic trailing routes, with eight routes that are used once, or twice per year (NPS 2018b).

In 2010, CARE assumed responsibility for managing grazing and trailing in the park, prompting an environmental assessment of grazing on park lands (NPS 2018b). Livestock grazing has historically been the primary disturbance to grasslands/shrublands in CARE (NPS 2018a), and CARE and NCPN staffs have monitored the recovery of grasslands/shrublands in the various grazing allotments since 2015 and 2007, respectively. The main impacts from livestock grazing are trampling disturbances to

biological soil crusts and reduced abundance of grasses, especially cool season grasses (Witwicki 2020). Recovery from livestock grazing is typically slow and incomplete in semiarid systems (Schwinning et al. 2008).

While in the past, cattle may have caused greater impacts to areas in CARE, today's impacts are being reduced through implementing actions identified in the Livestock Grazing and Trailing Management Plan (LGTMP) (NPS 2018b). For example, trailing occurs once or twice per year for limited time periods, with a limited number of cattle. Furthermore, it can be difficult to identify which stressor is acting on an ecosystem. Flash floods during monsoon season can cause many of the same impacts to riparian systems as those caused by cattle (NPS, M. Wehtje, biologist, review comment to riparian evaluation draft, 2 November 2021). So, with the park's ongoing monitoring, new information will continue to guide the NPS and permit holders for the long-term management of grazing and trailing in the park "…to promote the shared conservation and stewardship of the natural resources…" (NPS 2018b).

2.5. Air Quality (Pollution)

The NPS Air Resources Division (ARD) reports that air quality, ecosystems, and scenic resources can be affected by regional and local sources of air pollution, such as forest fires (natural or prescribed), dust created from land disturbance and natural sources, and pollutant emissions from combustion sources, such as vehicles, mining equipment, oil and gas development and coal-fired power plants. In the remote region surrounding CARE, emissions from power plants and oil and gas development are likely the most significant anthropogenic influences on air quality.



A scenic view from the Navajo Knobs Trail. On days without haze, the visual range at CARE is estimated at 322 km (200 mi), which is the maximum theoretical visible range. Image Credit: NPS.

There are numerous power plants in the larger southwestern region that have impacted air quality and scenic resources in nearby parks. However, emissions from many of these facilities have either decreased dramatically in the last decade or there are plans for the facilities that will decrease emissions significantly in the near future. This includes large facilities that are within 300 km (124 mi) of CARE: Hunter Power Plant, Huntington Power Plant, Intermountain Power Plant, and the Navajo Generating Station (Figure 2.5-1).

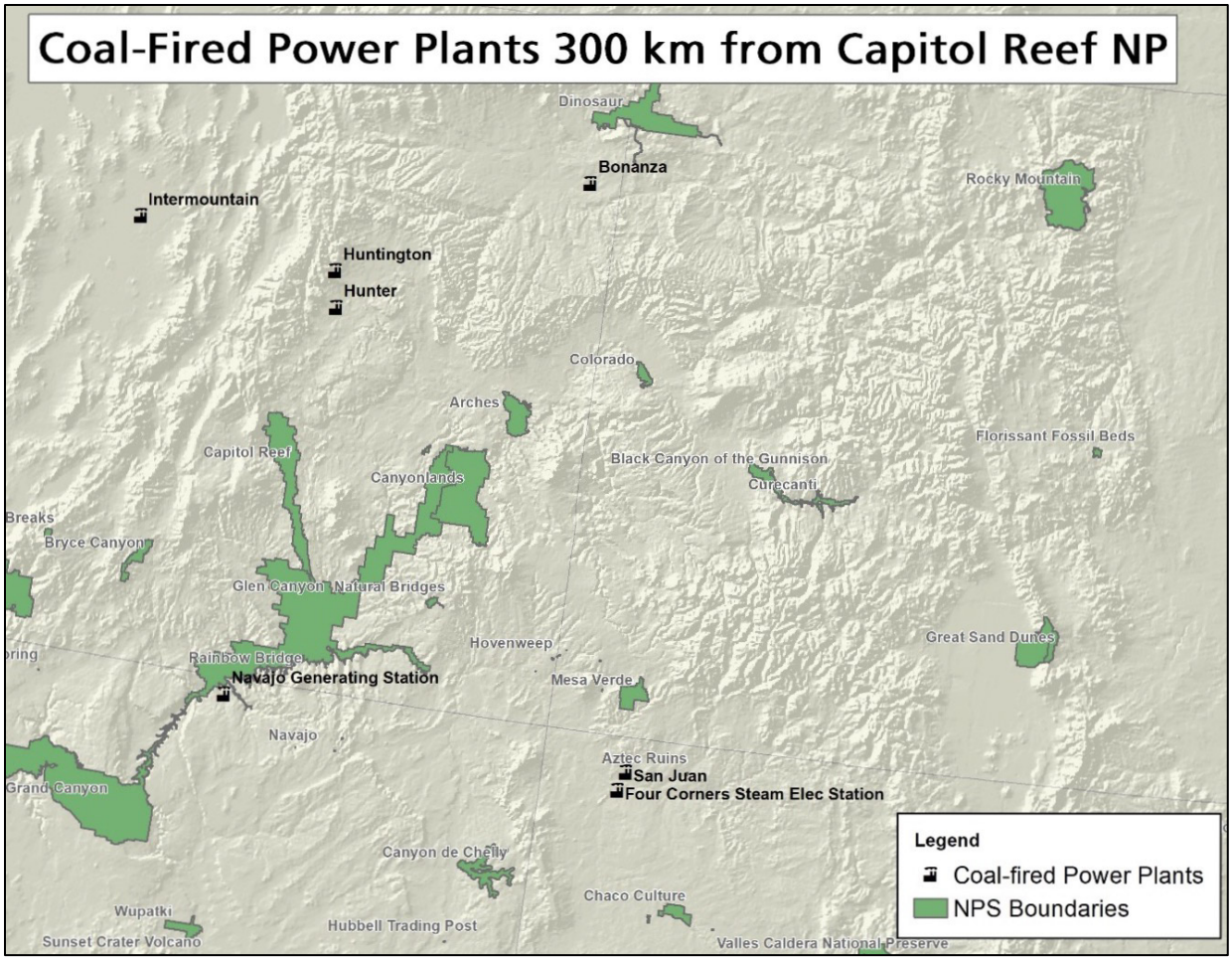


Figure 2.5-1. Locations of coal-fired plants 300 km (186.4 mi) from CARE. Figure Credit: NPS ARD.

The Navajo Generating Station near Page, Arizona permanently ceased operations on November 18, 2019. The Intermountain Power Plant in Delta, Utah is scheduled in 2025 for a replacement with an 840 MW natural gas plant that is designed to also burn "green hydrogen," with the company emphasizing hydrogen to be the main energy source. The Four Corners Power Plant near Fruitland on the Navajo Nation in New Mexico closed three out of five units in 2013. The remaining two units had top tier pollutant controls installed in 2018. In 2021, it was announced that one of the two remaining units will operate seasonally starting in fall 2023, while the other unit continues to run year-round. At the San Juan Generating Station near Waterflow, New Mexico (between Farmington and Shiprock), two of the four units shut down at the end of 2017. The remaining two units have installed some pollutant controls and are slated to close in 2022. However, these closures are not finalized; the plant may become a carbon dioxide capture facility and continue to operate.

The Bonanza Power Plant in Vernal, Utah, near the Utah-Colorado border, has installed some pollutant controls and taken some hour-operating limits. Additional potential controls are possible and would reduce emissions significantly. Some controls have been added to the Hunter and Huntington facilities to reduce regional haze impacts at nearby Class I areas, including CARE,

although additional potential controls could mean less emissions. There is a near-term opportunity to work with the Utah Department of Environmental Quality and the New Mexico Environment Department through the regional haze process to address some of these facilities, including Hunter and Huntington, that have not significantly reduced emissions in recent years. Recent trends in NO_x and SO_2 emissions from coal-fired electric generating units that affect CARE are provided in Figures 2.5-2 and 2.5-3. (Note: The graphs and maps below do not depict *all* point sources in the region, but just a subset of the coal-fired power plants.)

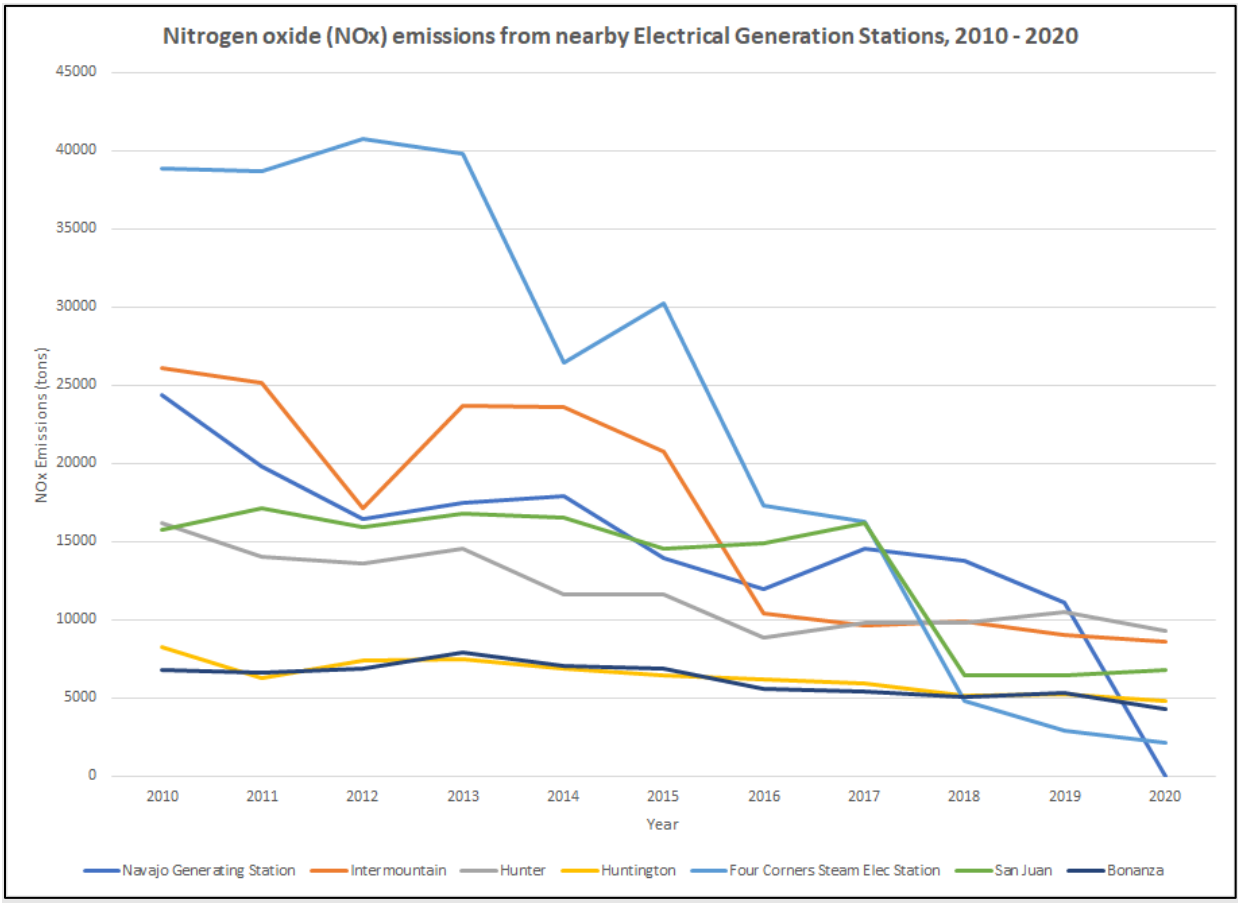


Figure 2.5-2. Nitrogen oxide emissions from electrical generating stations (2010–2020) that are within 300 km (124 mi) of CARE. Figure Credit: NPS ARD using Clean Market Divisions data (7/29–7/30/2021).

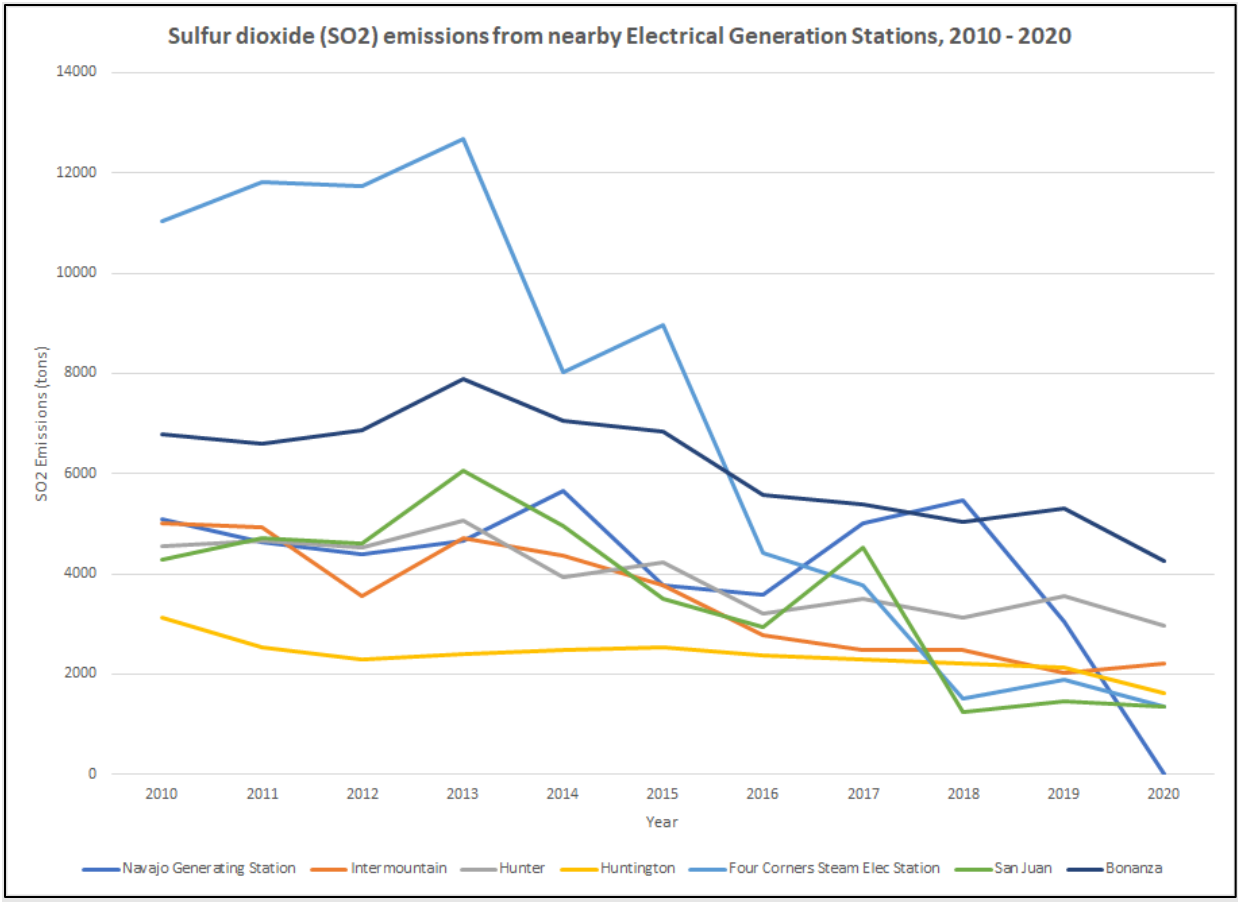


Figure 2.5-3. Sulfur dioxide emissions from electrical generating stations (2010–2020) that are within 300 km (124 mi) of CARE. Figure Credit: NPS ARD using Clean Market Divisions data (7/29–7/30/2021).

2.6. Resource Extraction

CARE is not within a major oil and gas basin, but it is in a region of Utah with two major basins nearby. The park may be affected by regional emissions from these oil and gas sources but does not have the direct impacts observed in parks located immediately adjacent to extensive development (e.g., Dinosaur National Monument).

The closest basin to CARE, the Paradox Basin, is east of the park (Figure 2.6-1). The Paradox Basin is older, with legacy development that began in 1956. As of July 2021, there were approximately 2,715 active or permitted oil and gas wells within the basin and one active drilling rig in Grand County, Utah. According to NPS Geologic Resources Division, there is one known oil and gas wellbore within the boundaries of CARE. This well, the Spring Canyon #1, was a "dry hole" and was plugged and abandoned in 1961. This well itself should pose no issues to park resources, but a routine survey of the area should be taken to ensure the well has remained closed (NPS, Forrest Smith, Petroleum Engineer, dataset via Enverus and summary provided in email, 10 February 2021).

Outside the park, there are two active gas wells within 8 km (5 mi) of CARE boundaries. These gas wells are owned and operated by the Byrd Frost company and were drilled in the 1950s. Both wells are in the small "Last Chance" field, a part of the larger Paradox Basin. Although their drill paths are

not explicitly stated on any state files, their age would indicate that they are both vertical shallow wells.

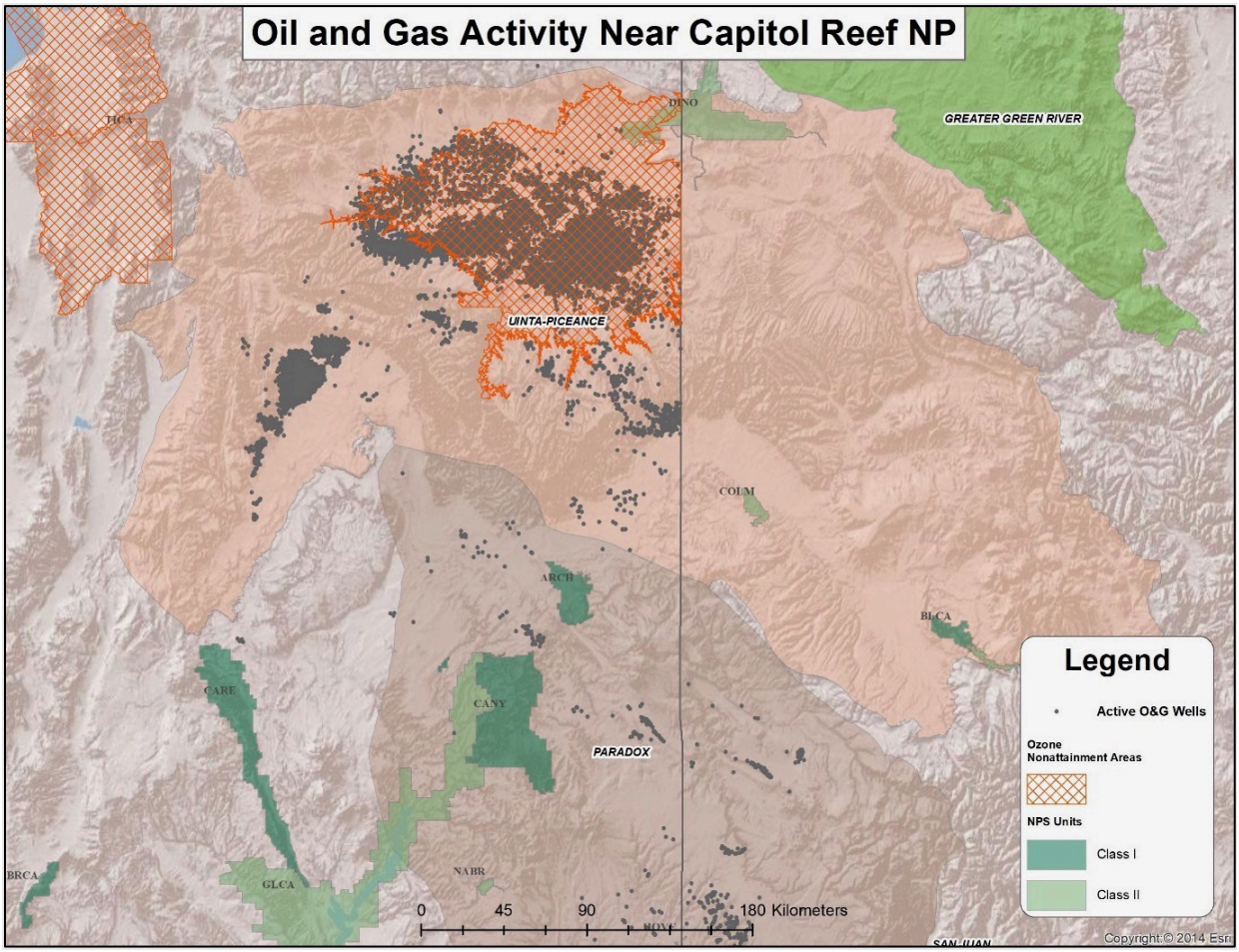


Figure 2.6-1. Oil and gas activity in the Uinta-Piceance and Paradox basins. Includes wells assigned as active, completed, drilled, or permitted. Figure Credit: NPS ARD using Drilling Info Database (7/30/2021).

More extensive development and the highest concentrations of active wells are within the Uinta-Piceance Basin (Figure 2.6-1). The Uinta Basin is in nonattainment status for ozone due to significant emissions from oil and gas sources. However, CARE is approximately 200 km (124 mi) southwest of the major development in the Uinta Basin and is not directly affected by the ozone nonattainment issues. As of July 2021, there were approximately 30,459 active oil and gas wells within the Uinta-Piceance Basin, spanning both the Utah and Colorado portions of the basin, with 13,090 wells on the Utah side alone.

The most recent comprehensive oil and gas inventory for the Paradox and Uinta-Piceance basins is available through the Western Regional Air Partnership (WRAP; 2021) regional planning organization. This oil and gas inventory was developed for a 2014 base year to support western states' regional haze planning efforts. Table 2.6-1 reports the 2014 emissions for upstream and midstream oil and gas point and area sources for the counties within these two basins. As reported in

Table 2.6-1 and Figure 2.6-2, emissions from the Paradox Basin are relatively low compared to other major basins in the western U.S., including Uinta (WRAP 2021).

Table 2.6-1. Annual oil and gas (area and point source) emissions (tons in 2014)(WRAP 2021).

Basin	Methane	NO_x	SO_2	VOC
Paradox	17,343	1,808	538	17,758
Uinta	571,530	30,443	501	192,086

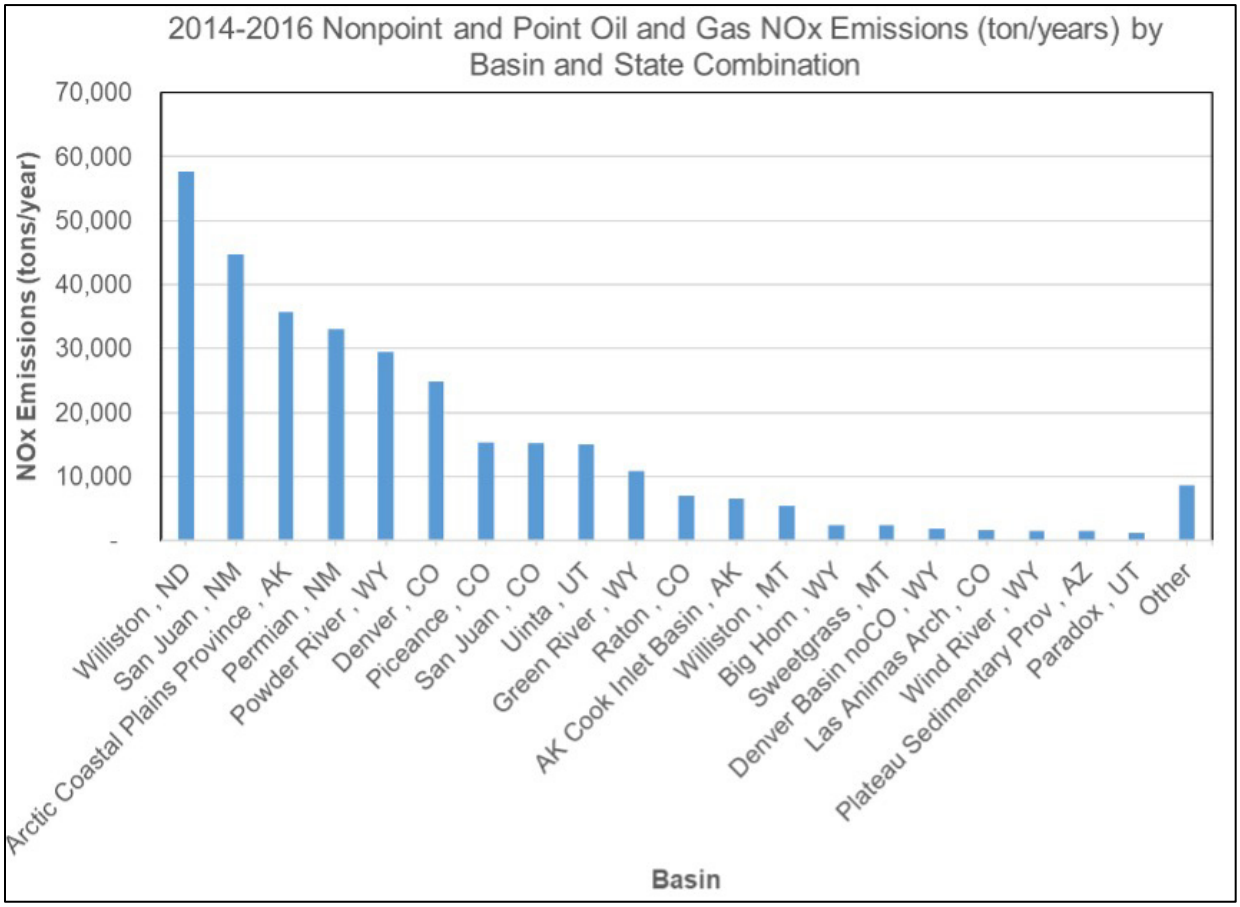


Figure 2.6-2. Non-point and point oil and gas emissions (2014–2016) in tons/year by basin and state (WRAP 2021). Figure Credit: NPS ARD.

NPS modeling studies (Sullivan et al. 2016a,b) indicate that emissions from oil and gas development may affect CARE by contributing to nitrogen deposition and ozone formation, but not to a significant extent (as compared to parks located much closer to extensive development). Cumulatively, nitrogen deposition and elevated ozone concentrations can harm sensitive vegetation and ecosystems (Thompson et al. 2017; NPS ARD 2020).

Although development near CARE is currently low relative to other regions of the country, proposals to lease and/or develop federal parcels near the park have occurred recently. Much of the oil and gas mineral estate near CARE is comprised of federal mineral ownership. Development of federally owned minerals provides an opportunity for coordination and consultation between the NPS and the BLM to ensure that park resources, such as air quality, are protected through mitigation and emission reduction measures as mineral development occurs. In addition, the NPS can work collaboratively with state air regulatory agencies to address air quality issues that may arise from oil and gas development near parks.

2.7. Climate Change

CARE has already experienced significant and rapid human-caused climate change (USGCRP 2017). Recent air temperatures have warmed and now routinely exceed the range of temperatures recorded from 1901 to 2012 (Monahan and Fisichelli 2014). Most notably, there has been a highly significant increase in night-time (daily minimum) temperatures over the past century, with most of the increase occurring since 1970. For the 1970–2018 period, daily minimum temperatures have increased at a rate of more than 8 °F per century ($P < 0.001$; analysis of PRISM data; Daly et al. 2008). Temperatures have also increased more in summer and fall than in other seasons. There has been no trend in precipitation over this period (Gonzalez et al. 2018a; Frankson et al. 2017; Figure 2.7-1a,b).

The NPS Climate Change Response Program (CCRP) evaluated historical climate conditions from PRISM climate data (Daly et al. 2008) and future climate projections for CARE using climate projections from 40 global climate models (Abatzoglou and Brown 2012; IPCC 2013). Simulations included low (representative concentration pathway [RCP] 4.5) and high (RCP 8.5) emissions scenarios using an ensemble of Multivariate Adaptive Constructed Analogs (MACA)-downscaled global circulation models (GCMs; Abatzoglou and Brown 2012). To facilitate planning, CCRP summarized model results into two divergent and plausible futures specific to CARE: a “Warm Wet” climate future, which from a water standpoint could be considered a “best case”, and a “Hot Dry” climate future that represents a much drier climate.

All global climate models evaluated ($n = 40$) project warmer temperatures relative to the 1950–2005 baseline (Figure 2.7-1a). For the 2025–2055 period (hereafter, circa 2040; shaded gray on Figure 2.7-1a,b,c), the Warm Wet average annual temperature increased about 3.6 °F; the days the minimum temperature dipped below freezing (<32 °F; frost days) decreased ~18 days/year (from 153 to 135 days/year); and the number of hot days (>95 °F) increased from ~2 to ~ 12 days/year. For the Hot Dry future during this same period, average annual temperature increased by 5.6 °F; frost days decreased by approximately 5 weeks (to ~ 115 days/year); and hot days above 95 °F increased by 23 days/year (from ~2 to ~25 days/year).

Projections of precipitation for circa 2040 range from a decrease of about 25.4 mm/year (1 in./year) to an increase of nearly 51 mm/year (2 in/year), with about 20% of projections indicating declining precipitation and 80% indicating increasing precipitation. In the Warm Wet future, precipitation increases, particularly in early summer, and drought severity, intensity, and duration increase (Figure 2.7-1b). In the Hot Dry future, summer precipitation amounts are similar to historical values.

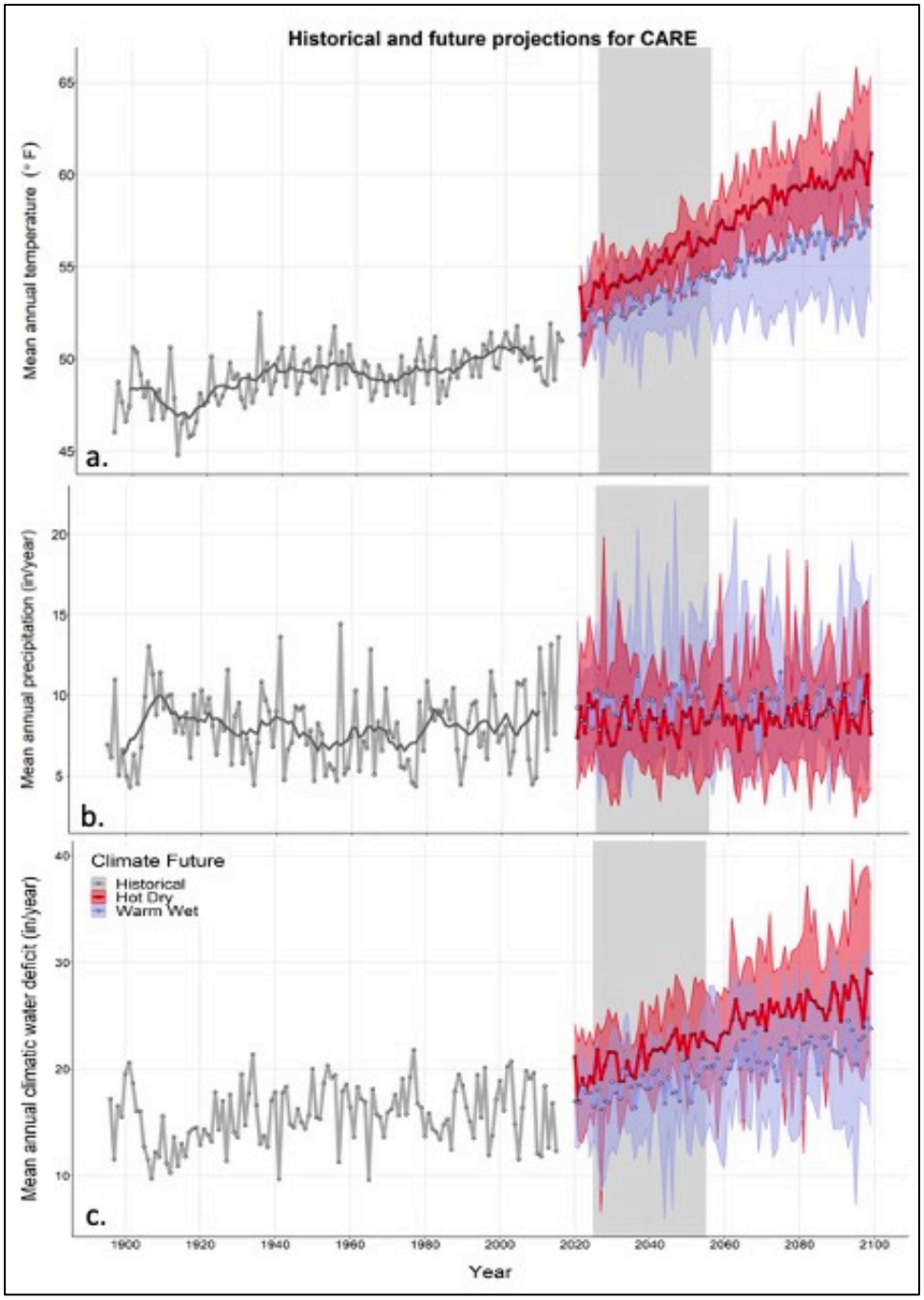


Figure 2.7-1. Historical climate observations (gray lines; PRISM records from 1895 to 2017; Daly et al. 2008) and future projections (red and blue lines; MACA-downscaled Global Climate Model [GCM] projections from 2020 to 2099) for (a) mean annual temperature, (b) mean annual precipitation, and (c) mean annual climatic water deficit in CARE. The dark gray line running through the historical time series is the 10-year running average. The red and blue lines represent the means of GCMs grouped into Hot Dry and Warm Wet climate futures; red and blue shaded areas represent the minimum-maximum range of each climate future. The gray shaded area represents the future time period 2025–2055 (circa 2040), used to average future changes from the historical baseline. Figure Credit: NPS CCRP.

Other projections consistently forecast changes in precipitation patterns. The Fourth National Climate Assessment predicts that precipitation throughout the Southwest region is more likely to occur during higher-intensity one- or two-day events, with 50–300% increases in the frequency of these events by the end of the 21st century (Easterling et al. 2017). These extreme events typically increase runoff, erosion, flooding, and other disturbances that can threaten park resources (USGCRP 2017). With increased runoff, a smaller portion of rainfall soaks into the ground and less water is available to plants. North American monsoon projections suggest that the overall amount of rainfall will remain similar to historic amounts, but the onset of the monsoon may be delayed by the end of the 21st century (Cook and Seager 2013). This means that precipitation may decline substantially in June and July, while increasing in frequency and amount in September and October. In addition, climate projections for the western United States predict that up to 60% of annual snowpack may be lost by 2050, with complete loss of snow at lower elevations in most years (Klos et al. 2014; Fyfe et al. 2017).

Warming temperatures will continue to increase atmospheric evaporative demand and that will increase landscape aridity even if precipitation remains constant or slightly increases (Bradford et al. 2020, Figure 2.7-1c). Higher climatic water deficits contribute to drier fuels and increased chance of fire ignition, increased drought stress on plants, reduced soil moisture, and reduced surface runoff (Westerling 2016; Thoma et al. 2020).

The NPS CCRP used a simple water balance model to evaluate the consequences of simultaneous changes in temperature and precipitation on soil moisture and water available for plant growth (Thoma et al. 2020). Moisture deficit is unmet water needs or the amount of water plants would use if it was available. Both the Warm Wet and Hot Dry climate futures indicate years with a much greater moisture deficit, and in many years, the projected moisture deficits far exceed any year in the recent historical record (Figure 2.7-1c). For the Warm Wet future circa 2040, the weather in many years–perhaps ~50%–would exhibit water deficits similar to average-to-dry observations from the recent past. But projected water deficits for the other ~50% of years in this period are similar to only the very driest years or much drier than any years in the past. For the Hot Dry future, almost all years are much drier than any year in the recent past.

Multiple studies found that greenhouse gas emissions and the resulting warming will lead to increased frequency of >10-year drought events, or "megadroughts" (Cook et al. 2015; Gonzalez 2018b). These droughts are similar in severity to the worst droughts of the 20th century but are much longer in duration (Ault et al. 2016). A Southwest megadrought has a 70% or higher chance of occurring by the end of the 21st century according to climate projections using a high-emissions scenario, even with moderate increases in precipitation (Ault et al. 2016).

Lower snowpacks and earlier snowmelts will likely affect hydrology, shifting the timing and amount of spring runoff towards earlier peak runoff and less runoff overall (Gonzalez et al. 2018b). The predicted changes in monsoonal and other seasonal precipitation vary between climate futures and make it difficult to predict changes in high discharge events. Interannual variability of precipitation is likely to increase, leading to abundant water in some years followed by extended periods of drought (USGCRP 2017).

Chapter 3. Focal Resource Evaluations

Chapter 3 reports on the conditions or states of CARE's selected focal natural resources. We evaluate these resources as either a condition assessment or gap analysis, depending on data availability (Figure 3-1).

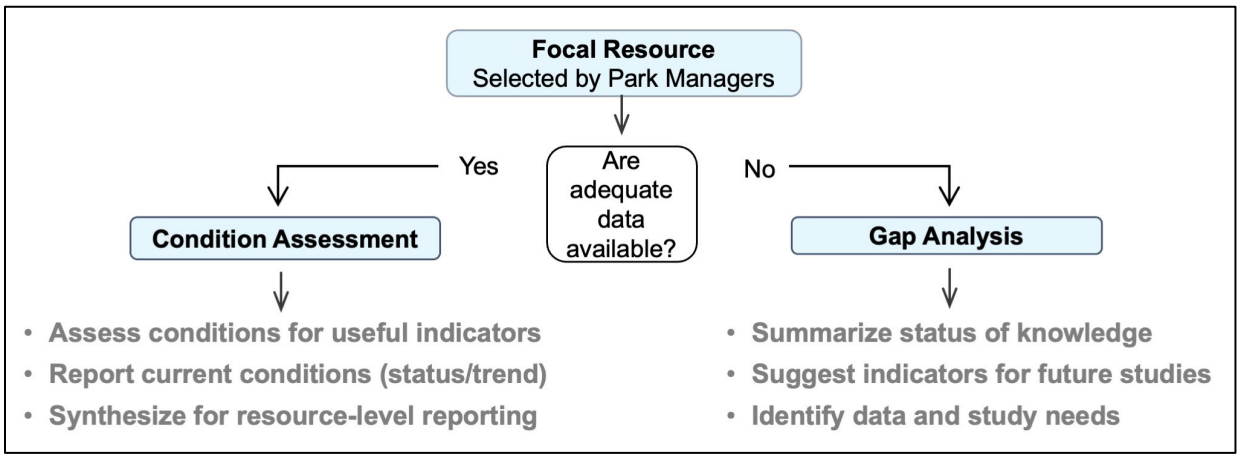


Figure 3-1. Two levels of evaluations are reported in NRCA studies depending on data availability: condition assessment and gap analysis.

For focal resources that lack adequate data for credible evaluations of their current conditions, we develop a gap analysis. A literature review, combined with expert input, produces a management-useful summary of the focal resource: its ecological importance, the general status of knowledge regarding factors influencing conditions, and useful data, indicators, and studies to consider in the future for improving managers' understanding of the resource.

For focal resources that have adequate data to assess current conditions for one or more indicators of condition, we develop a condition assessment. For each indicator, data for one or more measures are evaluated either qualitatively and/or quantitatively and combined to report a condition rating at the indicator level. Rating statements include the combined measures' qualitative characteristics, and when available, quantitative values, for a range of good to poor conditions for each indicator (see Figure 3-2 for rating classes and colors). Sometimes, the indicator of condition is unknown and shown in gray. The rating statements need to include logical and defensible criteria for assigning a condition level. We do not report a condition rating for the focal resource itself because of the complexity of characterizing condition at that level adequately.

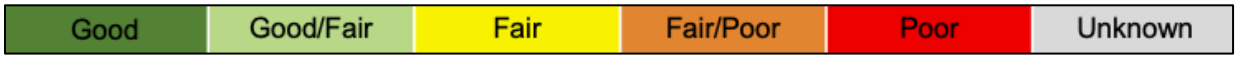


Figure 3-2. Indicators of condition rating classes and colors.

Each condition rating is assigned a confidence level, which is reported as high, medium, or low, depending on factors such as repeatability, age of data, and whether data were collected or modeled. A condition rating trend is reported as improving, stable, deteriorating, or unknown.

Natural resource condition assessments were completed for five focal resources: night sky and air quality, pinyon-juniper woodlands, grasslands and shrublands, songbirds, and fishes. Gap analyses were completed for six focal resources: soundscape, springs, seeps, & tinajas, riparian, rare plants, Mexican spotted owl, and desert bighorn sheep.



Falls at Gooseneck from Sulphur Creek. Image Credit: NPS.

3.1. Night Sky and Air Quality (Condition Assessment)

3.1.1. Background & Importance

Natural views depend on clear air for daytime scenic viewing and nighttime stargazing, which at CARE include, "… some of the most exceptional night skies [exist] in the world, as well as clean air, [and] spectacular scenery and views..." (NPS 2018a). CARE is designated a Class I area, receiving special protection for its air quality and visibility (Clean Air Act 42 U.S.C. §7401 et seq.).

Haze, caused by airborne particulates that reduce how well and how far people can see, obscures daytime scenic views and nighttime stargazing. For example, on a clear day, park visitors can see the colors and rich textures of the cliffs, canyons, and rock formations distinctly at farther distances. And at night, CARE has an exceptionally dark night sky. It has been an International Dark-Sky Park since 2015 (IDSA n.d.)—one of only 43 U.S. national parks with this designation. The town of Torrey, UT, which is the gateway community to CARE, was designated a dark-sky community in 2018, managing sources of light pollution to maintain the region's pristine night skies (IDSA n.d.). However, the ability to see extends beyond aesthetic values and affects a wide range of species, ecosystems, and natural physical processes (Moore et al. 2013). Natural light intensity varies during the day/night (diurnal), lunar, and seasonal cycles, and organisms have evolved to respond to these periodic changes in light levels in ways that control or influence movement, feeding, mating, emergence, migration, hibernation, and dormancy, and vegetation growth, including direction (Royal Commission on Environmental Pollution 2009).

Given CARE's rich ethnographic history, the park has a unique opportunity to provide educational programs that help visitors "visualize" the cultural heritage of the Desert Archaic Indians, the Fremont Culture, the Ancestral Southern Paiutes, and the Utes (Sucec 2006), and the Mormon settlers (White 1994; Crampton 1965), and their relationships to night- and daytime views.



Pectol's Pyramid from the Hickman Bridge Trail. Image Credit: © ZOLTAN G. LEVAY.

3.1.2. Study Framework

This assessment is an integrated evaluation of current conditions for night sky and air quality at CARE. We evaluated CARE's night sky using two measures of illuminance (amount of light falling onto a given surface area), two measures of luminance at the zenith (the amount of light passing through the atmosphere), one measure that describes the amount of anthropogenic light pollution, and two semi-quantitative measures of sky quality (Table 3.1.2-1; NPS NSNSD 2016). The NPS Natural Sounds and Night Skies Division (NSNSD) and CARE staff collected the night sky data. The condition rating statements for the night sky indicators of condition are in Appendix B, Table B-1 (Moore et al. 2013; Hung et al. 2019).

Table 3.1.2-1. Study details for the night sky condition assessment (NPS NSNSD 2016).

Indicator of Condition	Measure	Reference Criteria for Measure	Description
Illuminance	Horizontal illuminance (mlux)	≤0.8	This measure is the amount of light striking the ground (horizontal).
	Maximum vertical illuminance (mlux)	≤0.4	This measure is the amount of light striking a vertical plane facing the brightest part of the sky near the horizon.
Luminance	Synthetic sky quality meter (SQM) (mag/arcsec^{-2})	≥21.60	A value derived from the all-sky measurements using an algorithm designed to mimic the response of the Unihedron Sky Quality Meter. Considered more accurate than an actual measure. Measurements are made at the zenith.

Table 3.1.2-1 (continued). Study details for the night sky condition assessment (NPS NSNSD 2016).

Indicator of Condition	Measure	Reference Criteria for Measure	Description
Luminance (continued)	Handheld SQM (mag/arcsec^{-2})	≥21.60	Same as above except that data were collected by CARE staff using a handheld Unihedron Sky Quality Meter.
Anthropogenic Light Pollution	All-sky light pollution ratio (ALR)	<2.00	This measure describes light due to man-made sources compared to light from a natural dark sky.
Sky Quality	Bortle Dark-Sky Scale (class)	1–3	This measure describes the quality of the dark night sky be the celestial bodies and night sky features an observer can see. Lower values indicate darker skies (1–9 scale).
	Limiting magnitude	6.8–7.6	The faintest stars than can be observed visually without optical aid (naked eye) near the zenith, or darkest part of the sky.

We evaluated CARE's air quality using two indicators: visibility (haze index) and ozone as it relates to human health (Table 3.1.2-2; NPS ARD 2021a). Although haze is a measure of daytime visibility, it also influences the visibility of stars and planets in the night sky. NPS ARD air quality indicators of condition are in Appendix B, Table B-2 (NPS ARD 2021a).

Table 3.1.2-2. Study details for the air quality condition assessment (NPS ARD 2021a).

Indicator of Condition	Measure	Reference Criteria for Measure	Description
Visibility	Haze index (deciviews (dv))	<2	Haze index is based on the chemical composition of air samples to determine range of visibility and degree of impairment.
Ozone	Human Health (ppb)	≤54.9	The human health measure is the 5-year average of the 4th-highest daily maximum 8-hour average ozone concentrations.

3.1.3. Data & Methods

Night sky data were collected at 14 locations in CARE (Table 3.1.3-1 and Figure 3.1.3-1), but not every measure was collected at each location. NPS NSNSD scientists collected data at Burr Trail Switchbacks (2005–2007, 2019), Goosenecks Overlook (2004, 2019), and Panorama Point (2005) (NPS NSNSD 2004, 2005a,b,c, 2006a,b; 2007, 2019a,b). In some years, data were collected on more than one night (n = 9 for each measure).

Table 3.1.3-1. Summary of night sky data collected at CARE.

Site	Measure						
	Horizontal Illuminance	**Maximum Vertical Illuminance**	**Synthetic SQM**	**Handheld SQM**	**ALR**	**Bortle Dark-Sky Class**	**Limiting Magnitude**
Burr Trail Switchbacks	2005–2007, 2019	2005–2007, 2019	2005–2007, 2019	2014–2020	2005–2007, 2019	2007, 2014, 2016, 2017, 2019	2007, 2019
Capitol Gorge Parking	–	–	–	2014, 2016, 2018, 2019	–	2016	–
Capitol Reef Field Station	–	–	–	2014	–	–	–
Cathedral Campground	–	–	–	2014, 2016, 2017, 2019, 2020	–	–	–
Cedar Mesa Campground	–	–	–	2014–2020	–	2014, 2016, 2017	–
East Entrance	–	–	–	2014, 2016–2020	–	2016	–
Fruita Campground	–	–	–	2014, 2016, 2019	–	–	–
Goosenecks Overlook	2004, 2019	2004, 2019	2004, 2019	–	2004, 2019	2019	2019
Halls Creek Overlook	–	–	–	2014–2020	–	2014, 2016, 2017	–
Panorama Point	2005	2005	2005	2014, 2016–2020	2005	2016, 2017	–
Pleasant Creek Trailhead	–	–	–	2016–2020	–	2016, 2017	–
Slickrock Divide	–	–	–	2014–2020	–	2014–2017	–
Visitor Center	–	–	–	2014, 2016–2020	–	2016, 2017	–
West Entrance	–	–	–	2014, 2016–2019	–	2016, 2017	–

NPS NSNSD scientists and park staff made Bortle observations at 12 locations, with between two and five measurements per location (NPS NSNSD 2007, 2019a,b; NPS NCPN, C. Livensperger, plant ecologist, data file sent to Lisa Baril, Utah State University, 13 July 2021). Data were collected more than once in a single year at a given site (n = 32).

CARE staff also used a handheld Unihedron Sky Quality Meter (SQM) at 13 locations from 2014 to 2020 as part of a long-term monitoring program at the park (NPS, C. Livensperger, plant ecologist, data file sent to Lisa Baril, Utah State University, 13 July 2021), although there are earlier measurements for some sites that were collected by NPS NSNSD (n = 133).

The air quality visibility indicator is monitored through the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program, using the haze index measure, which is expressed in deciviews (dv) or standard visual range in miles (mi). The haze index is a measure of aerosol particles in the atmosphere, and sulfates, nitrates, chloride (sea salt), coarse mass, soot, and organics all contribute to haze (NPS ARD 2021a). Because there is an IMPROVE monitor located at CARE (CAPI1) (Figure 3.1.3-1), trends in visibility were reported using the 5-year (2014–2018) haze index averages on the 20% haziest days and on the 20% clearest days. Consistent with the Clean Air Act and Regional Haze Index Rule goals of improving visibility on the haziest days and no deterioration on the clearest days, if the haze index trend on the 20% clearest days is deteriorating, the overall trend is reported as deteriorating. Otherwise, the trend on the 20% haziest days is reported as the overall visibility trend (NPS ARD 2021a). Information for CARE's visibility condition and trend was obtained from NPS ARD's website (NPS ARD 2021b).

The air quality ozone indicator is monitored across the U.S. by networks operated by the NPS, U.S. Environmental Protection Agency (USEPA), states, and others (NPS ARD 2021a). Aggregated ozone data are acquired by NPS ARD from the USEPA Air Quality System database. We used these data to evaluate the condition of ozone as it relates to human health, which is reported as the 4th-highest 8-hour concentration in parts per billion (ppb) (NPS ARD 2021b).

The annual 4th-highest daily maximum 8-hour ozone concentrations were averaged over a 5-year period (2014–2018) and interpolated across all ozone monitoring locations across the contiguous U.S. (NPS ARD 2021b). The ozone human health value reported for CARE is the maximum estimated value derived from this national analysis because there are no on-site or nearby monitors.

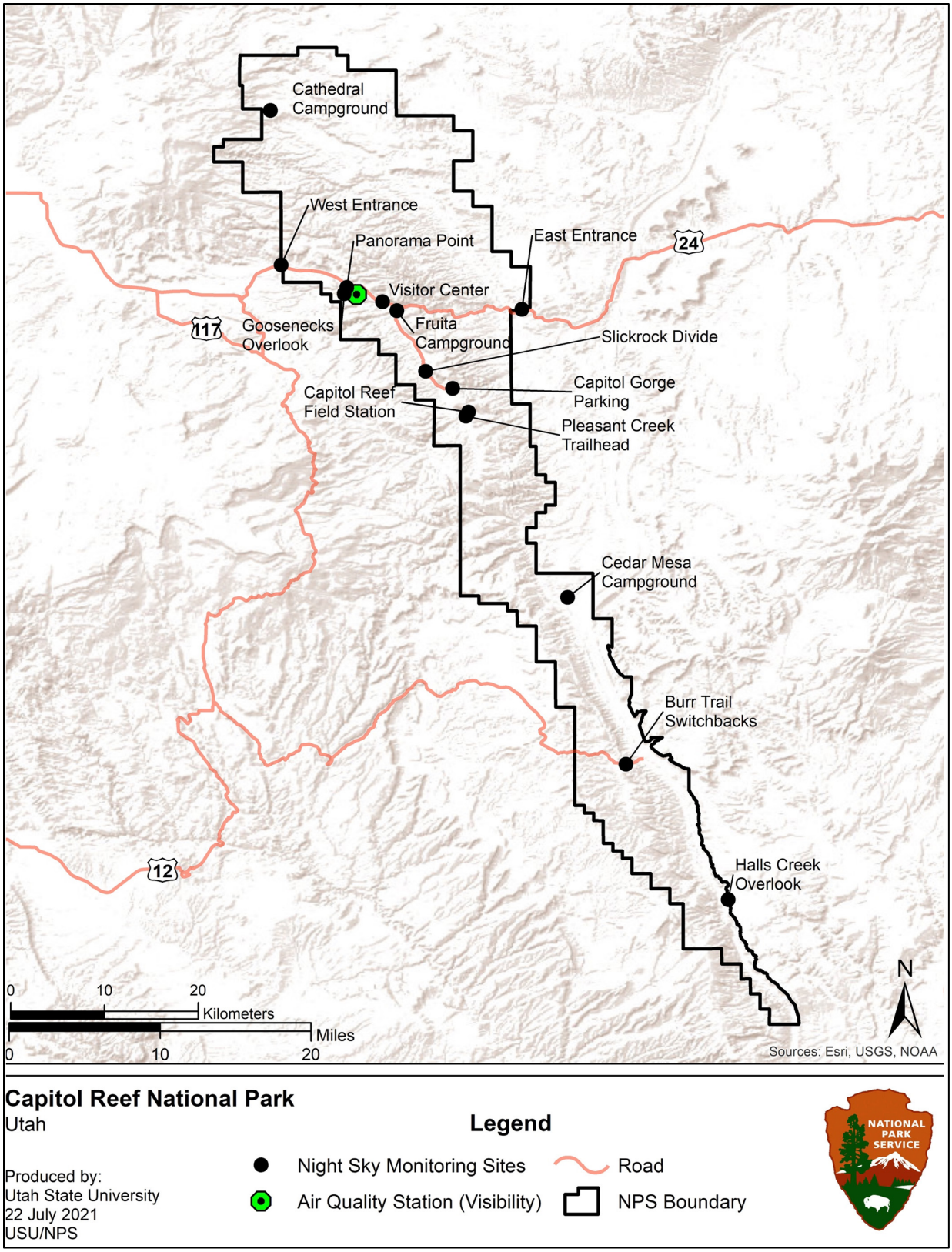


Figure 3.1.3-1. Night sky and air quality monitoring locations in CARE.

3.1.4. Results & Discussion

Illuminance

Horizontal illuminance across all sites averaged 0.82 mlux, with a range of 0.62 to 1.1 mlux (Figure 3.1.4-1). Horizontal illuminance averaged 0.84 mlux from 2004 to 2007 at Burr Trail Switchbacks, Goosenecks Overlook, and Panorama Point, and 0.79 mlux in 2019 at Burr Trail Switchbacks and Goosenecks Overlook. The latter value met the reference criterion of 0.8 mlux, while the former value was slightly above the reference criterion, indicating a slightly degraded condition. The overall mean indicates a potentially degraded condition.

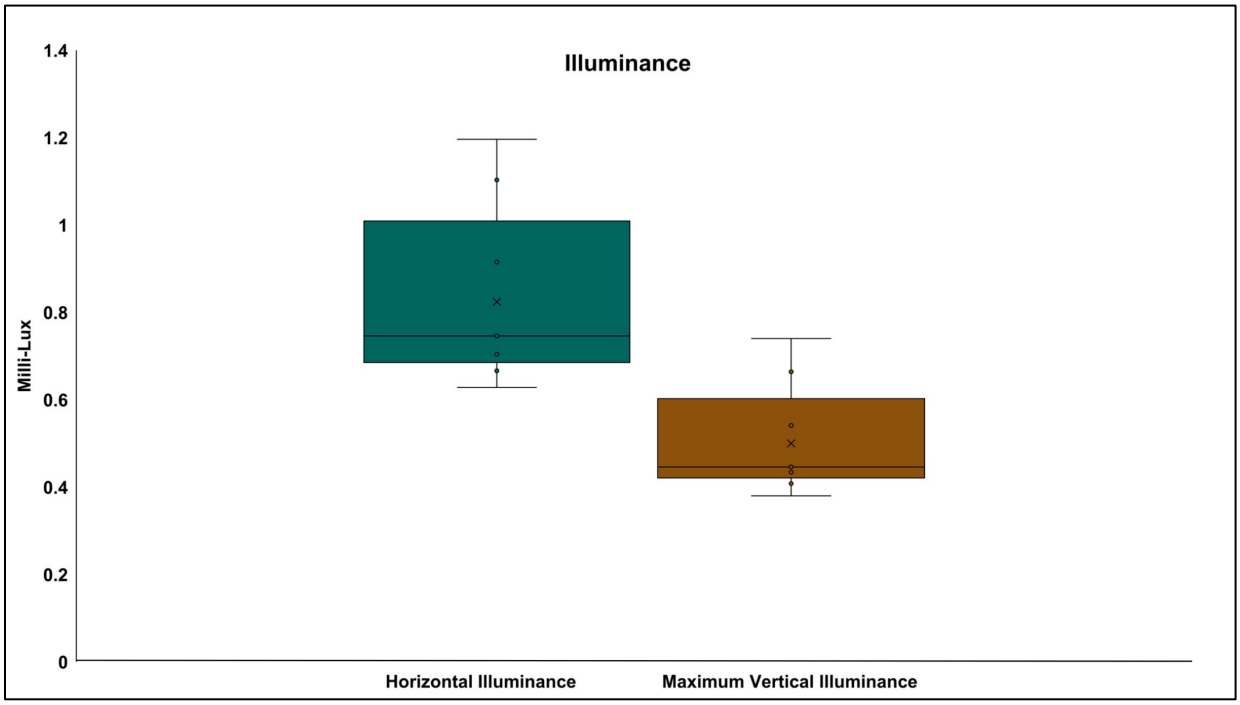


Figure 3.1.4-1. Horizontal and maximum vertical illuminance measurements that were collected at three locations from 2004 to 2007 and at two locations in 2019 in CARE.

Maximum vertical illuminance across all sites averaged 0.50 mlux, with a range of 0.38 to 0.74 mlux (Figure 3.1.4-2). Maximum vertical illuminance averaged 0.51 mlux from 2004 to 2007 at Burr Trail Switchbacks, Goosenecks Overlook, and Panorama Point, and 0.47 mlux in 2019 at Burr Trail Switchbacks and Goosenecks Overlook. Similar to horizontal illuminance, the overall mean was slightly above the reference criterion value of 0.4 mlux, indicating a slightly degraded condition. Because reference criteria have not been developed for all condition class ratings, the level of confidence in the good/fair condition rating is medium. Not enough data were collected to determine trends or to evaluate any differences by location.

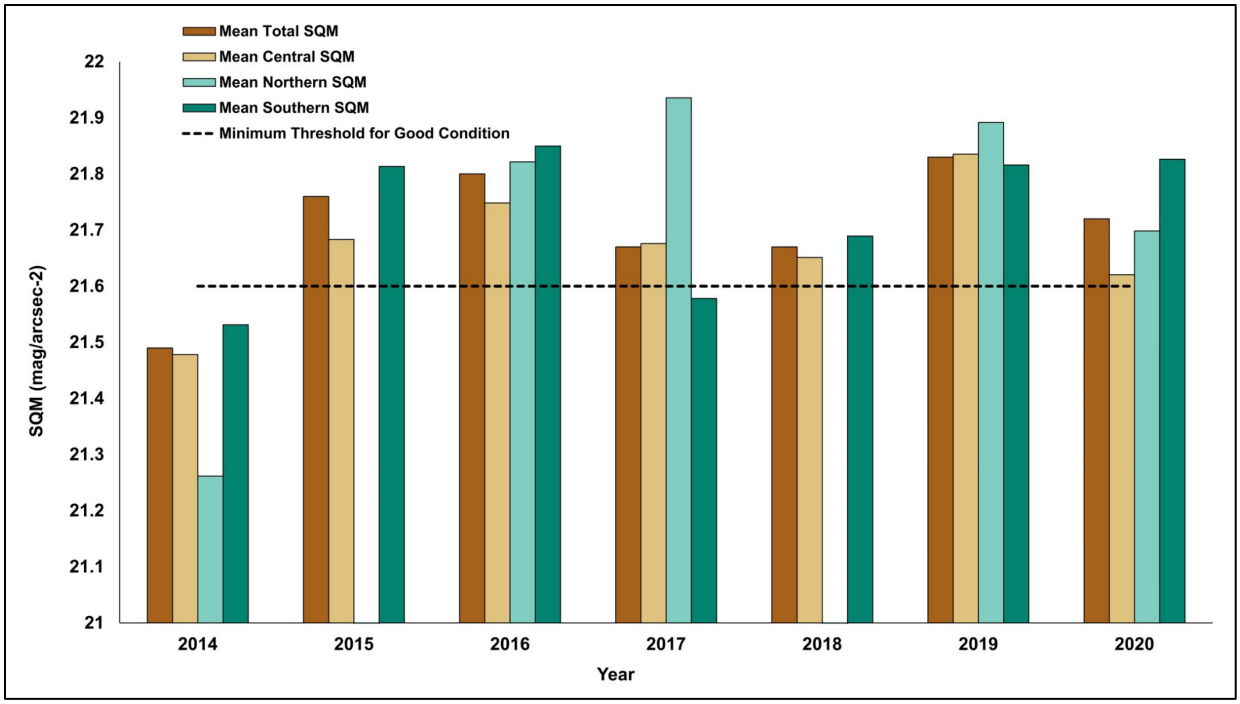


Figure 3.1.4-2. Hand-held sky quality meter (SQM) means from 2014 to 2020 for park-wide, central, northern, and southern locations.

Synthetic SQM averaged 21.60 mag/arcsec^{-2} from 2004 to 2007 at the three sites with data (i.e., Burr Trail Switchbacks, Goosenecks Overlook, and Panorama Point). Values for two of those sites (Burr Trail Switchbacks and Goosenecks Overlook) averaged 21.65 mag/arcsec^{-2} in 2019. These values suggest good condition, but sample size is extremely small.

The handheld SQM measurements (n = 133) averaged 21.70 mag/arcsec^{-2} from 2014 to 2020 (Figure 3.1.4-2). Mean annual values met the good condition reference criterion, except during 2014. Because of the large data set gathered over many years, we also looked for patterns by area of the park (i.e., three southern locations, 11 central locations, and one northern location). We considered Cathedral Campground as the single northern location and Cedar Mesa Campground, Burr Trail Switchbacks, and Halls Creek Overlook as the three southern locations. The remaining 11 sites were included in the central group. Again, except for 2014 and the southern sites in 2017, all areas of the park met the reference criteria for a good condition rating. Confidence in the condition rating is high because of the large and relatively long-term data set, and the trend appears stable.

In 2007, the modeled ALR was 0.04, which indicates the night sky was 4% brighter than average natural conditions. Field values for ALR averaged 0.03 (i.e., 3% brighter than average natural conditions) from 2004 to 2007 at three sites (Burr Trail Switchbacks, Goosenecks Overlook, and Panorama Point) and ranged from 0.0 to 0.07 (Figure 3.1.4-3). More recent ALR values for two of those sites (Burr Trail Switchbacks and Goosenecks Overlook) averaged 0.07 (i.e., 7% brighter than average natural conditions) in 2019. These values met the reference criterion for a good condition

rating, but the confidence level is medium because of the limited (n = 2) and modeled data. Trends could not be determined because of the small sample size.

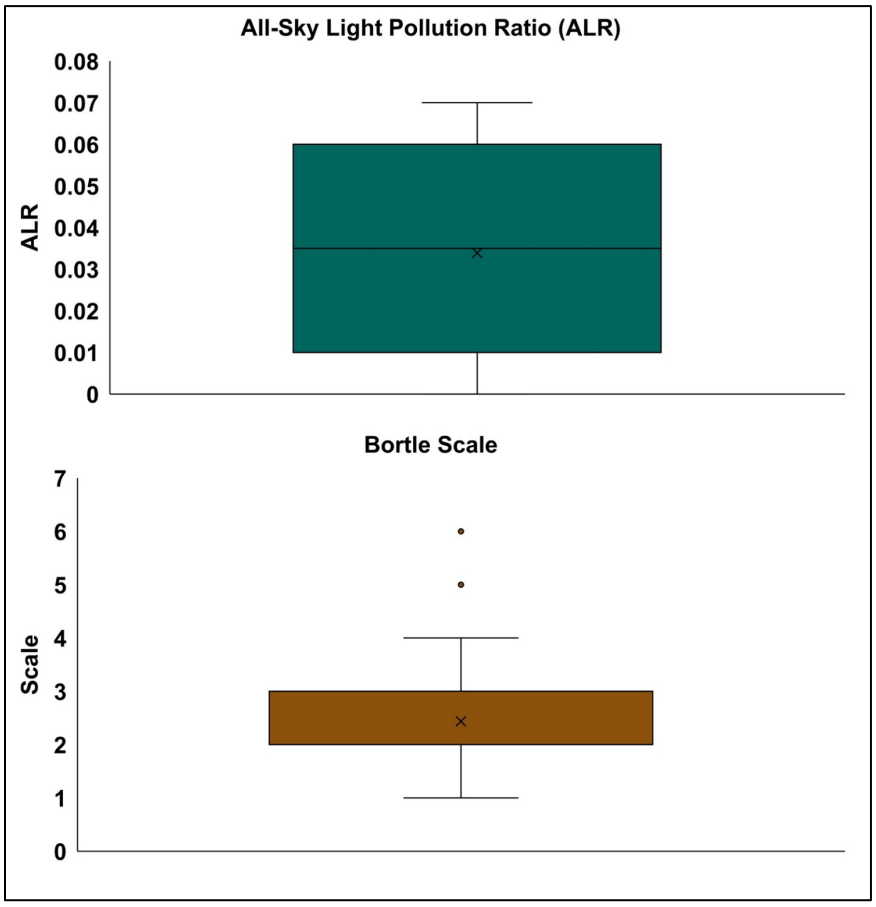


Figure 3.1.4-3. All-sky light pollution ratio (top) and Bortle Dark-Sky Scale (bottom) data at CARE.

The Bortle class ratings averaged 2.4 across all sites, which is between a typical, truly dark sky and a rural sky, but values ranged from 1 to 6 (Figure 3.1.4-3). While most values recorded during the six years of monitoring were rated at 3 or less, in 2014, the readings taken at the Burr Trail Switchbacks, Cedar Mesa Campground, and Halls Creek Overlook exceeded the reference criterion of 1 to 3. The criterion was also exceeded in 2017 at the Pleasant Creek and Visitor Center monitoring locations. NPS ARD (2021b) air quality data do not indicate a particularly hazy year in 2014, but light extinction from 2009 to 2018 was the highest at the park in 2017 (Figure 3.1.4-4). However, cloud cover or other factors could have contributed to these higher recorded values in 2014 and 2017.

The second measure for determining the condition of sky quality is limiting magnitude, which averaged 7.1 for two sites in 2019 and 7.2 for one site in 2007. These values are within the reference range of 6.8–7.6.

Based on the Bortle class and limiting magnitude results, the sky quality condition is good. Trend appears stable based on the Bortle class data; however, CARE staff have not received training on

implementing the Bortle Dark-Sky Scale, and there is wide variability in observer skill in applying this measure (NPS, C. Livensperger, biologist, comments to draft assessment, 11 August 2021). Trends in limiting magnitude could not be determined. Confidence is medium because there were few data on limiting magnitude and because both measures rely on observer ability, which can vary by observer.

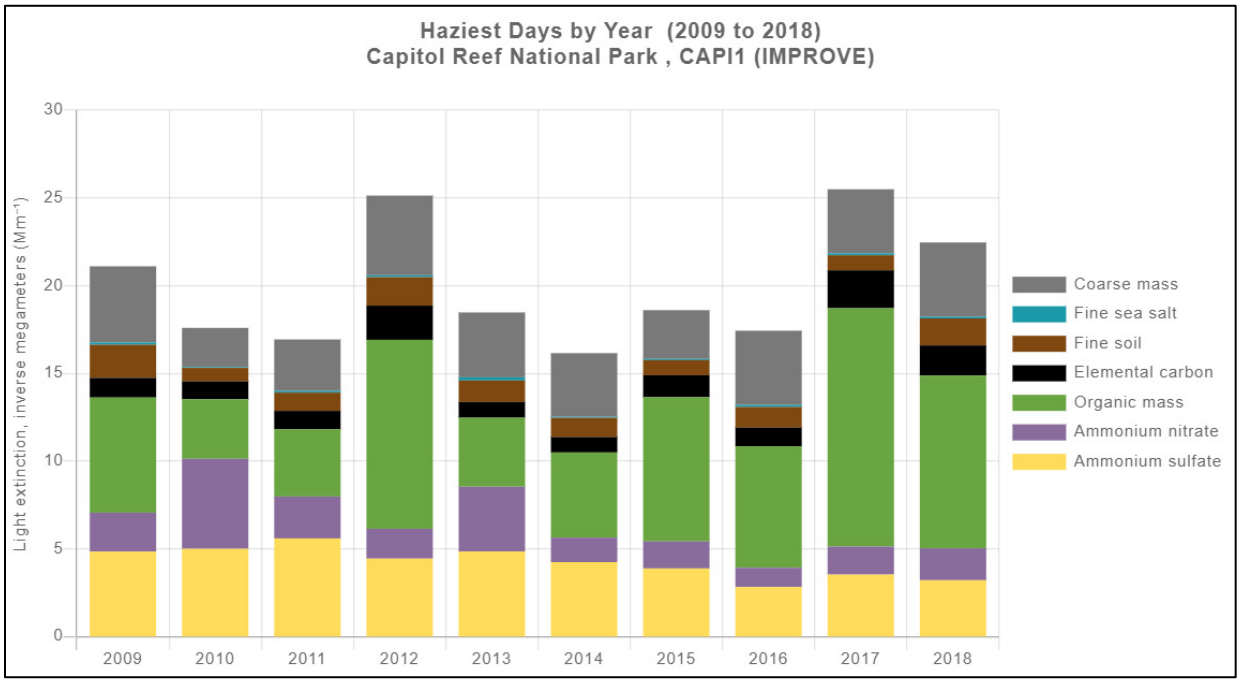


Figure 3.1.4-4. Particle composition of annual light extinction on haziest days from 2009 to 2018. Figure Credit: NPS ARD 2021b.

The air quality visibility indicator of condition is fair based on the 5-year average (2014–2018) haze index on mid-range days minus the natural visibility on mid-range days. For 2009–2018, the 10-year trend in visibility remained relatively unchanged on the 20% clearest days and 20% haziest days, resulting in an overall unchanged visibility trend (NPS ARD 2021b). "The small variability in measured values over the years…[indicate] atmospheric differences between sampling sites," (NPS, B. Meadows, physical scientist, comments to draft evaluation, 16 September 2021).

The major contributors to haze from 2014 to 2018 included organic mass, ammonium sulfate, and coarse mass (Figure 3.1.4-4). Other haze contributors included fine sea salt, fine soil, elemental carbon, and ammonium nitrate. Although these components, except for elemental carbon, would be present under natural conditions (i.e., in the absence of human activities or natural background condition) (USEPA 2003), current levels have resulted in a doubling of light extinction (i.e., loss in light intensity due to scattering and absorption) (NPS ARD 2021b). In 2018 (the most recent year for which data were available), the months with the highest haze impairments were July, August, and December (Figure 3.1.4-5). These were not, however, the months with the highest visitation that year (NPS Stats 2021a, although we acknowledge that visitation, and by extension, the number of vehicles in the park, likely reduces air quality at the local scale).

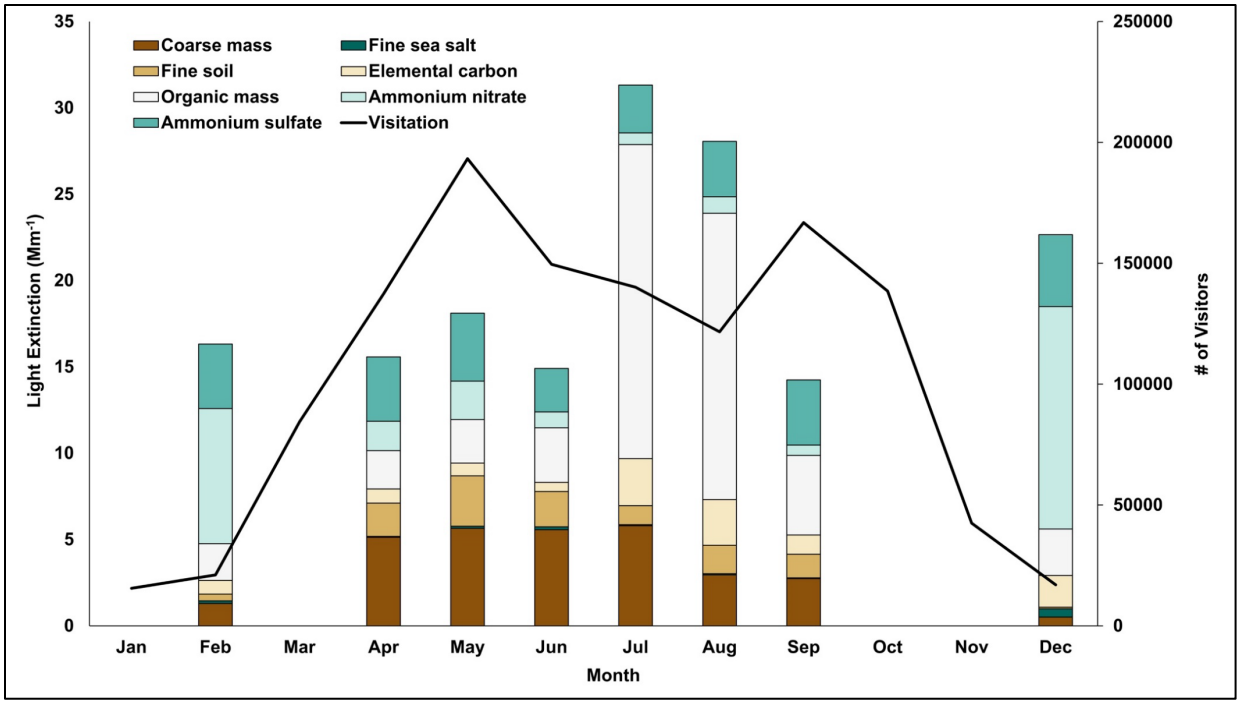


Figure 3.1.4-5. Particle composition of monthly average light extinction on haziest days in 2018. Data credit: NPS ARD 2021b.

In 2018, the measured visual range at CARE was 138–288 km (86–179 mi). Without the effects of pollution, the estimated visual range would be 204–317 km (127–197 mi) (NPS ARD 2021b). Although the condition for the haze index is fair—a common occurrence across the Colorado Plateau region—the condition of night skies at CARE is of high quality, and the confidence in the condition rating is high because there is an in-park monitor.

For the air quality ground-level ozone measure, concentrations are fair based on the 5-year average (2014–2018) estimated concentration of 69.8 ppb. Trend is unknown because there are insufficient on-site or nearby ozone monitoring data available. Confidence in the condition rating is medium because estimates are based on interpolated data from more distant ozone monitors.

Chemical reactions between oxides and pollutants that are emitted by cars, power plants, etc., in the presence of sunlight form ground-level ozone, and as park visitation increases, the number of vehicles also increases. From 1992 to 2020, the mean traffic count was stable at 200,851 vehicles until 2009, after which traffic counts rose substantially (refer to Figure 3.2.2-4 in the soundscape gap analysis). While differences in counting methods may explain some of the increase in apparent traffic, CARE visitation (as in many parks) has increased substantially in recent years. From 2016 to 2019, visitors exceeded one million annually (NPS Stats 2021b).

Vehicle exhaust and dust from off-highway vehicles (OHV) may contribute to haze in the park, and additional local stressors include oil and gas development next to the park. Although the BLM deferred a planned lease sale, which was scheduled for July 2020, the potential for oil and gas development near the park has not been eliminated (Pollard 2020). Not only may nearby oil and gas

developments contribute to poor air quality, but lights associated with infrastructure may diminish the dark night skies typically found at CARE. Similarly, other developments surrounding the park from increasing populations and other types of infrastructure could introduce additional light pollution into the park. However, overall, the night sky indicators of condition are good, and the air quality indicators of condition are fair (Table 3.1.4-1).

Table 3.1.4-1. Night sky and air quality condition ratings summary.

Indicator	Condition Rating [1]	Trend	Condition Evaluation
Illuminance	Good/Fair	Unknown	Both horizontal and vertical illuminances averaged slightly above their reference criteria, resulting in a good/fair condition rating. Confidence in the rating is medium because reference criteria have not been formally established for all levels of condition. There were insufficient data to determine trends.
Luminance	Good	Stable	Synthetic SQM averaged 21.60 from 2004 to 2007 at three sites. Values for two of those sites averaged 21.65 in 2019. These values indicate good condition. Handheld SQM measurements averaged 21.70 from 2014 to 2020. Mean annual values were well within the good condition rating except during 2014, and confidence is high due to the large data set. Trend appears stable.
Anthropogenic Light Pollution	Good	Unknown	In 2007, the modeled ALR was 0.04. Field values for ALR averaged 0.03 from 2004 to 2007 at three sites. ALR values for two of those sites averaged 0.07 in 2019. These values are well within the condition considered good. Trends could not be determined. Due to limited recent data (n = 2) and modeled data from 2007, confidence is medium.
Sky Quality	Good	Stable	The mean Bortle class was 2.4, and limiting magnitude averaged 7.1 for two sites in 2019 and 7.2 for one site in 2007. Combined measures indicate a good sky quality condition. Trend appears stable based on the Bortle data but could not be determined for limiting magnitude. Confidence in the condition rating is low because of observer variability.
Visibility	Fair	Stable	Daytime visibility is fair based on the 5-year average (2014–2018) haze index. For 2009–2018, the 10-year trend in visibility remained relatively unchanged on the 20% clearest days and 20% haziest days, resulting in an unchanged visibility trend. Confidence in the condition rating is high because there is a monitor in the park.

[1] See Appendix B and, Tables B-1 and B-2 for the 5-level condition rating statements for each indicator.

Table 3.1.4-1 (continued). Night sky and air quality condition ratings summary.

Indicator	Condition Rating [1]	Trend	Condition Evaluation
Ozone	Fair	Unknown	Ground-level ozone concentrations are fair based on the 5-year average (2014–2018) estimated concentration of 69.8 ppb. Trend is unknown because there are not sufficient on-site or nearby ozone monitoring data for the park. Confidence in the condition rating is medium because estimates are based on interpolated data from more distant ozone monitors.

[1] See Appendix B and, Tables B-1 and B-2 for the 5-level condition rating statements for each indicator.

While local sources affect CARE's air quality, regional sources, such as forest fires (natural or prescribed), dust from agriculture and other types of land disturbance, and pollution emissions from combustion, such as mining equipment, oil and gas development, and coal-fired power plants, may be the most influential on park air quality. There is even evidence to suggest that climate change-induced drought increases fine dust particles in the atmosphere (Achakulwisut et al. 2018), which could be particularly bad on windy days (NPS, C. Livensperger, biologist, comments to draft assessment, 11 August 2021). Furthermore, nitrogen deposition is more likely to cause changes in plant communities and increase the growth rate of invasive species in physically disturbed areas (NPS, M. Bell, biologist, comments to draft assessment, 17 August 2021).

According to the USEPA (2020), in the United States, roughly two thirds of all sulfur dioxide (SO_2) and one quarter of all NO_x originate from electric power generation that relies on burning fossil fuels. Sulfur dioxide and nitrogen oxides are released from power plants and other sources, and ammonia is released by agricultural activities, feedlots, fires, and catalytic converters. In the atmosphere, these transform to sulfate, nitrate, and ammonium, and can be transported long distances across state and national borders (USEPA 2020).

In recent years, many coal-burning, power-generating stations in the U.S. have shut down, leaving 20 coal plants operational in the West (Los Angeles Times 2020). Several other coal-fired plants around the region are at various stages of being decommissioned, which should lead to better air and water quality in and around CARE in the future. On December 18, 2020, the largest coal-fired plant in the Western U.S.–the Navajo Generating Station's–smokestacks were demolished (The Salt Lake Tribune 2020). At its peak capacity, the station produced 2.25 gigawatts of electricity (Lustgarten 2015; Sierra Club n.d.), and "….at one time [was] the third-largest emitter of greenhouse gases in the U.S." (Bloomberg Law 2020). The station ceased operation in late 2019 but had been emitting greenhouse gases and pollutants for decades. CARE is one of eight national parks previously affected by haze from the Navajo Generating Station (USEPA 2013).

We could not integrate scenic views into the night sky and air quality assessment; however, we provided an integrated approach to the two resource topics. Events that may trigger a re-evaluation of these resources include oil and gas development adjacent to the park, other developments

surrounding the park, changes in lighting plans for nearby and distant communities, and certain types of maintenance and/or development within the park.

3.2. Soundscape (Gap Analysis)

3.2.1. Background & Importance

A park's acoustic environment is an inherent component of the NPS Organic Act of 1916 and should remain "…unimpaired for the enjoyment of future generations" (16 U.S.C. 1 2 3, and 4; 39 Stat. 535). CARE identifies natural sound as a significant resource and an important wilderness value (NPS 2018a), and sounds of nature and quiet are some of the most important reasons visitors identify for spending time in national parks (Haas and Wakefield 1998). Environments without noise pollution are also important to wildlife and their ability to avoid predators, perform courtship rituals, and effectively use their habitats, which all depend on the ability to hear. Studies show that wildlife can exhibit avoidance behaviors due to increased noise levels (McLaughlin and Kunc 2013; Shannon et al. 2015), and while the severity of impact varies by species, documented responses include increased heart rate, startle responses, flight, disruption of behavior, separation of mothers and young, and interference with communication (Selye 1956; Clough 1982; USFS 1992; Anderssen et al. 1993; NPS 1994a; Dooling and Popper 2007; Kaseloo 2006).

Plant communities may be adversely affected by noise because key pollinators and seed disperses will avoid certain areas (Francis et al. 2012). This may be especially important for managing CARE's historic fruit orchards, whose blossoms depend on pollination for fruiting success in an area of the park that also "sustains the highest level of visitor use…" (NPS Stats 2021a; NPS 2007). As the park's backcountry use continues to increase, it is likely that disturbances to natural sound and impacts to wildlife will also increase, especially as visitation patterns change with the changing climate (see Wilkins et al. 2020 video for research on how weather affects visitor movement at CARE). If managers understand the visitation patterns at the park, strategic planning and preventative actions can safeguard resources and inform the types and scales of needed infrastructure to manage visitor use and its associated disturbances to a natural acoustic environment.



The Scenic Drive is a popular visitor attraction at CARE. Image Credit: NPS / ARIEL SOLOMON.

3.2.2. Status of Knowledge

Park staff collected acoustic data at three locations beginning in August 2020: Highway 24 East, Pleasant Creek, and Cathedral Valley (Figure 3.2.2-1). The acoustic lab analyses of these data were being completed at the time of this report (NPS, E. Brown, biologist, and Tammy Cook, NRCA project manager, personal communication to K. Struthers, 28 January 2021). However, the NPS NSNSD developed a geospatial model from 2013 to 2015 that estimates sound pressure levels for the continental United States using actual acoustical measurements combined with a multitude of explanatory variables, such as location, climate, landcover, hydrology, wind speed, and proximity to noise sources (e.g., roads, railroads, and airports) (NPS 2015a; Turina et al. 2013).

The 270-m (886-ft) resolution geospatial model predicts daytime sound levels during midsummer. Each pixel on the map represents the sound pressure level at which there is a 50% chance of exceeding the median value of the pixel (L_{50}). The decibel (dB) values are A-weighted (dBA), which is an adjustment that reflects how the human ear perceives sounds. While the model excels at predicting acoustic conditions over large landscapes, it may not reflect recent localized changes, such as new access roads or other types of developments that increase the presence of noise sources. A new sound model is in development that will reflect the 2020 U.S. Census Bureau data and other updated model inputs (NPS, E. Brown, biologist, phone call, 18 May 2021).

CARE's predicted sound level impact is the model's primary measure of interest and is the difference between existing and natural ambient sound levels (Turina et al. 2013). This impact value is a measure of how much human noise contributes to the existing natural soundscape at a given location. Reference criteria for non-urban parks like CARE (i.e., 90% of the park area is located outside of an urban environment), are more stringent than for urban parks. A mean impact of ≤1.5 dBA is good, an impact value that is > 1.5 and ≤ 3.0 dBA is fair, and a mean impact value above 3.0 dBA is poor (Turina et al. 2013). Another way to interpret these values is to look at the corresponding reduction in the listening area for a given impact value. For example, "a 3 dB increase in background sound levels reduces the area from which you could previously have heard a natural sound by 50%" (NPS 2020a). Thus, at a 1.5 dB increase, the listening area is reduced by 30% (Turina et al. 2013).

The mean existing sound level at CARE is estimated at 35.6 dBA, and the mean L_{50} impact is estimated to be 2.4 dBA, which indicates a fair condition of sound level park-wide and a reduction in the listening area of 43%. However, different areas have different sound levels, depending on their proximity to noise sources.

Much of the park is zoned as primitive (63.5%) and semi-primitive (29.6%) management zones. These two zones, along with most of the threshold zone (6.4%), are managed for their wilderness value, which includes the preservation of the natural soundscape (NPS 1998). The remaining zones are small in area but have an outsized effect on the park's soundscape, particularly the road corridor (0.2%) and rural development (0.2%) zones (NPS 1998). Anthropogenic noise is expected to be more frequent and louder in these zones than in the backcountry. The utility corridor zone (~0.1%) has not been mapped, so we could not calculate noise in this zone; however, the noise levels are likely the same as the zones in which the utilities are embedded, except during repairs and routine maintenance when noise levels increase.

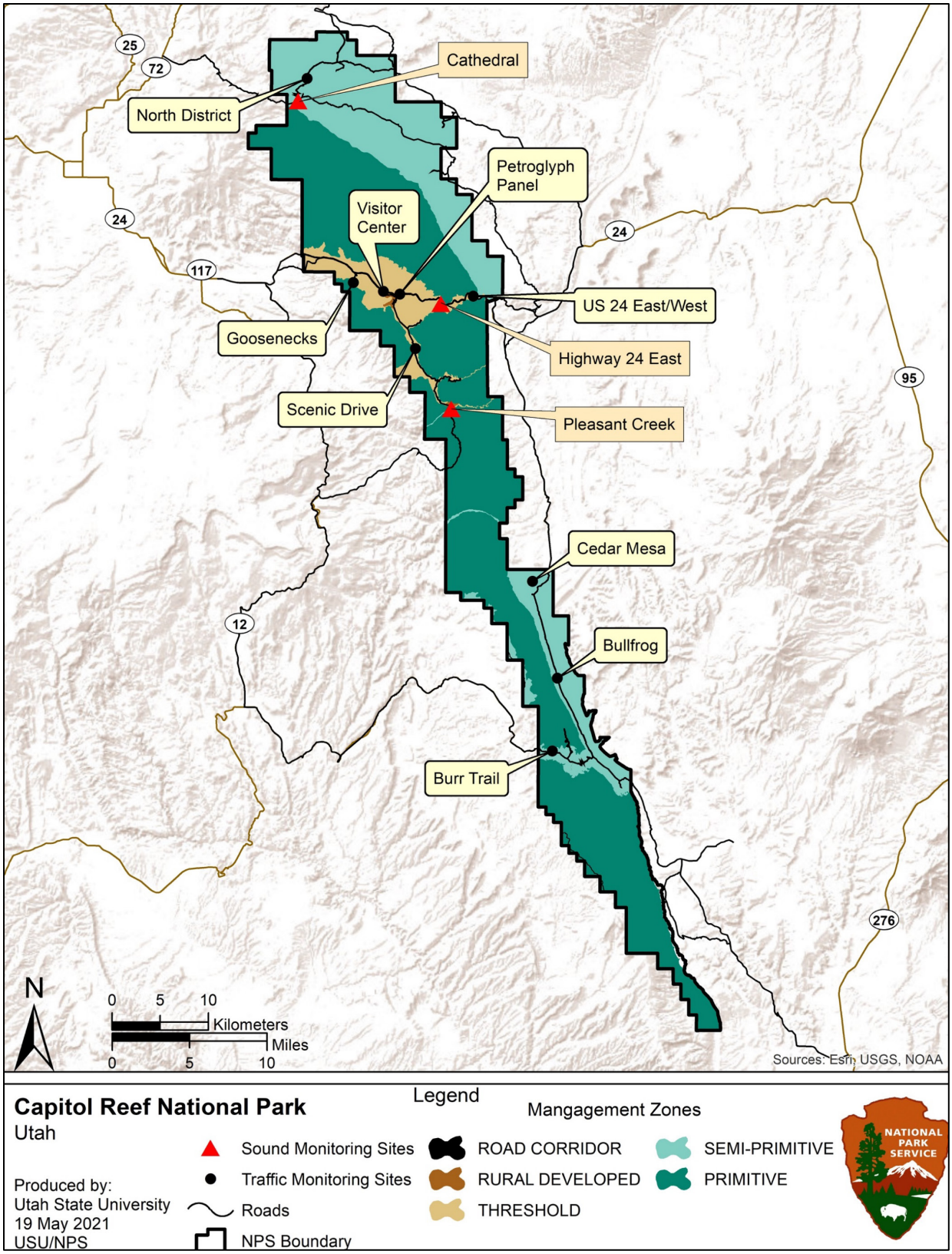


Figure 3.2.2-1. Management zones, locations of the three 2020 sound monitoring sites, and approximate locations of the nine traffic monitoring sites in CARE.

The mean impact sound levels were lowest in the primitive and semi-primitive management zones, higher in the threshold zone, and highest in the road corridor and rural zones (Figure 3.2.2-2). The values predict fair conditions for the primitive and semi-primitive zones, while the remaining three zones are predicted to be in poor condition. However, there is wide variability within each zone. For example, impact levels in the primitive, semi-primitive, and threshold zones span all three condition rating categories, and the geospatial model of sound impact levels park-wide suggests that roads and nearby communities are areas of higher sound impacts (Figure 3.2.2-3).

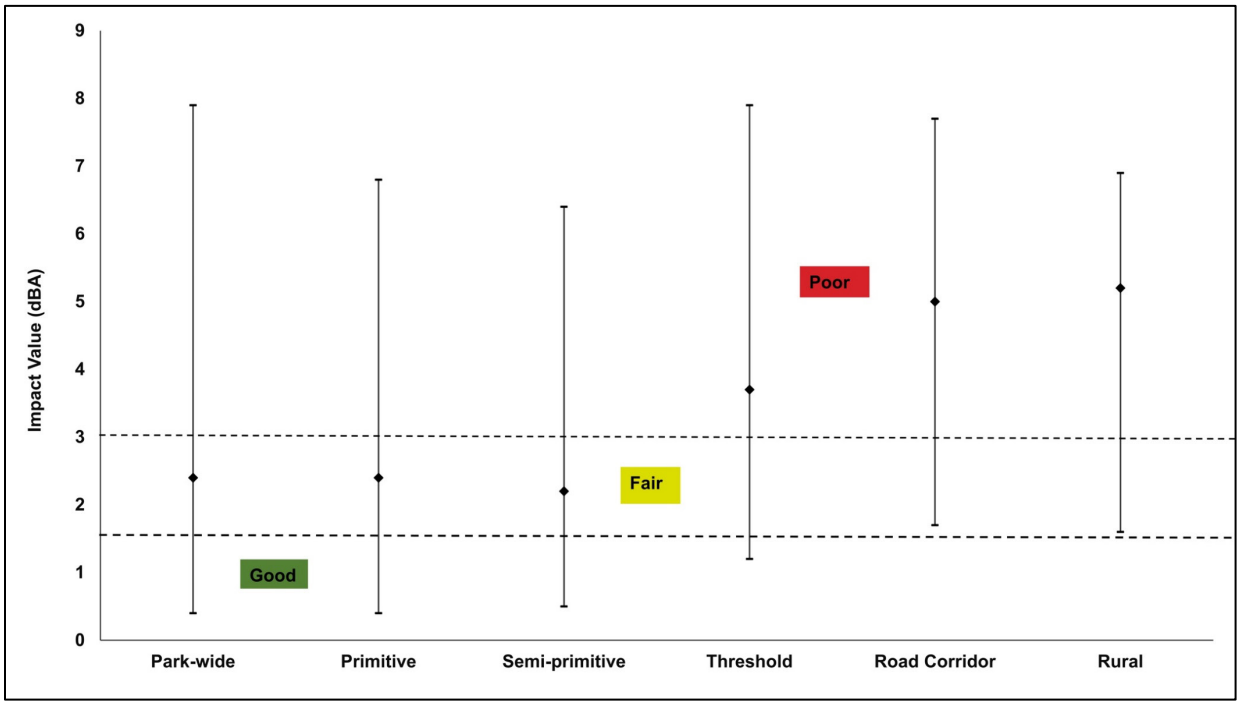


Figure 3.2.2-2. Sound level impact data (maximum, minimum, mean) averaged park-wide and for each of five management zones. The dashed lines demarcate the three condition classes: good, fair, and poor.

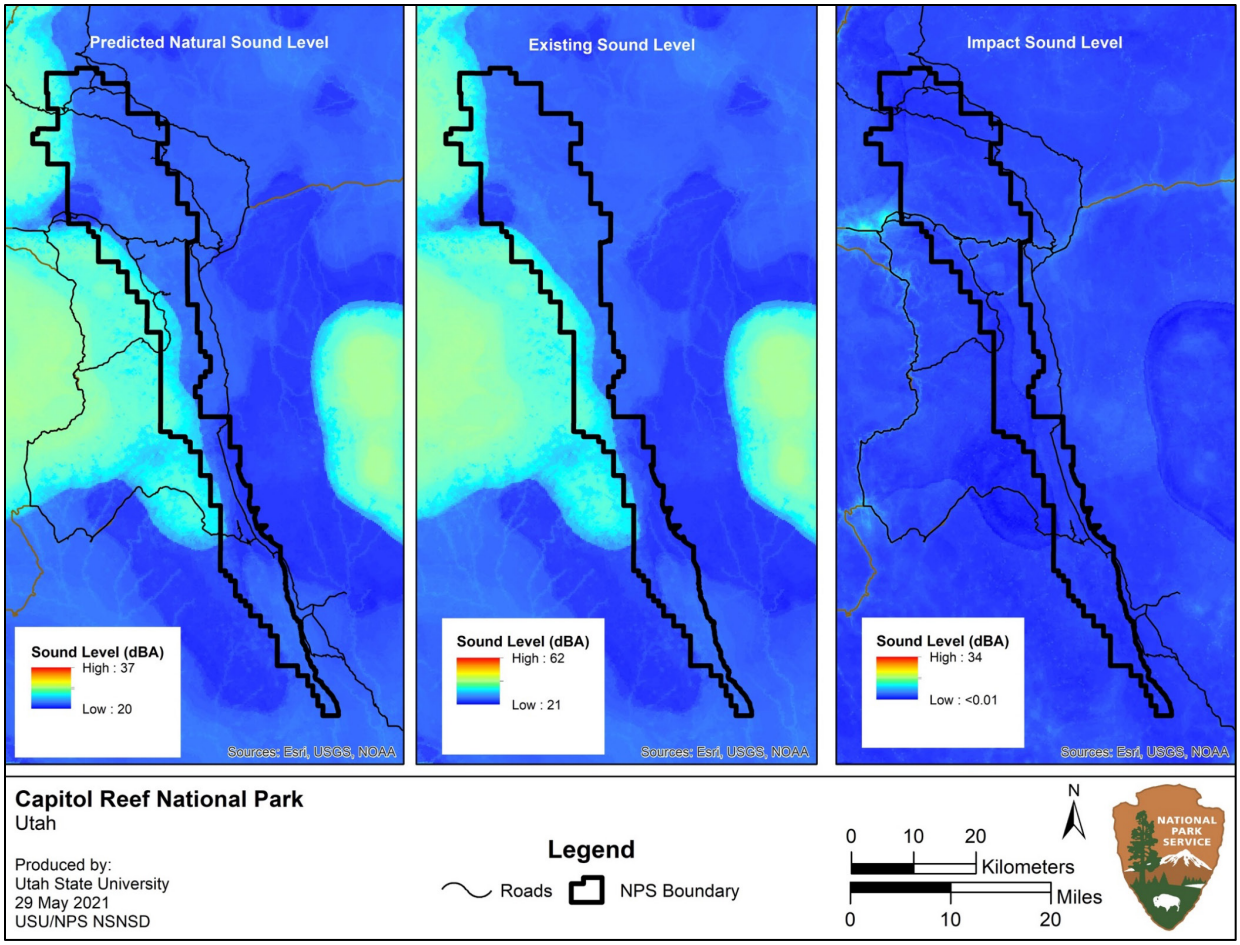


Figure 3.2.2-3. Sound model maps of the predicted natural, existing, and impact sound levels in and around CARE. Note the different scales in each map.

According to traffic count data collected from 1992 to present at nine locations in CARE (NPS Stats 2021a), May–September are the busiest months (Figure 3.2.2-4). Because the sound impact model is predictive for an average summer day, we summarized traffic count data from May through August, be we also report total annual traffic counts.

From 1992 to 2020, the mean traffic counts were stable at 200,851 vehicles until 2009, after which traffic counts rose substantially (Figure 3.2.2-4). Most of this increase occurred at the Visitor Center, Highway 24, Petroglyph, Goosenecks and Scenic Drive sites (Figure 3.2.2-5). Highway 24 is the primary road through the park, and the Visitor Center, Petroglyph Panel, Scenic Drive, and Goosenecks are popular attractions accessed from this road (see Figure 3.2.2-1 for traffic count locations). And because this is a state highway, all types of vehicles (e.g., 18-wheel trucks) may pass through. Lowering speed limits, restricting the use of engine brakes, establishing rules against idling vehicles, and repaving road surfaces with quieter materials could help reduce noise from the highway.

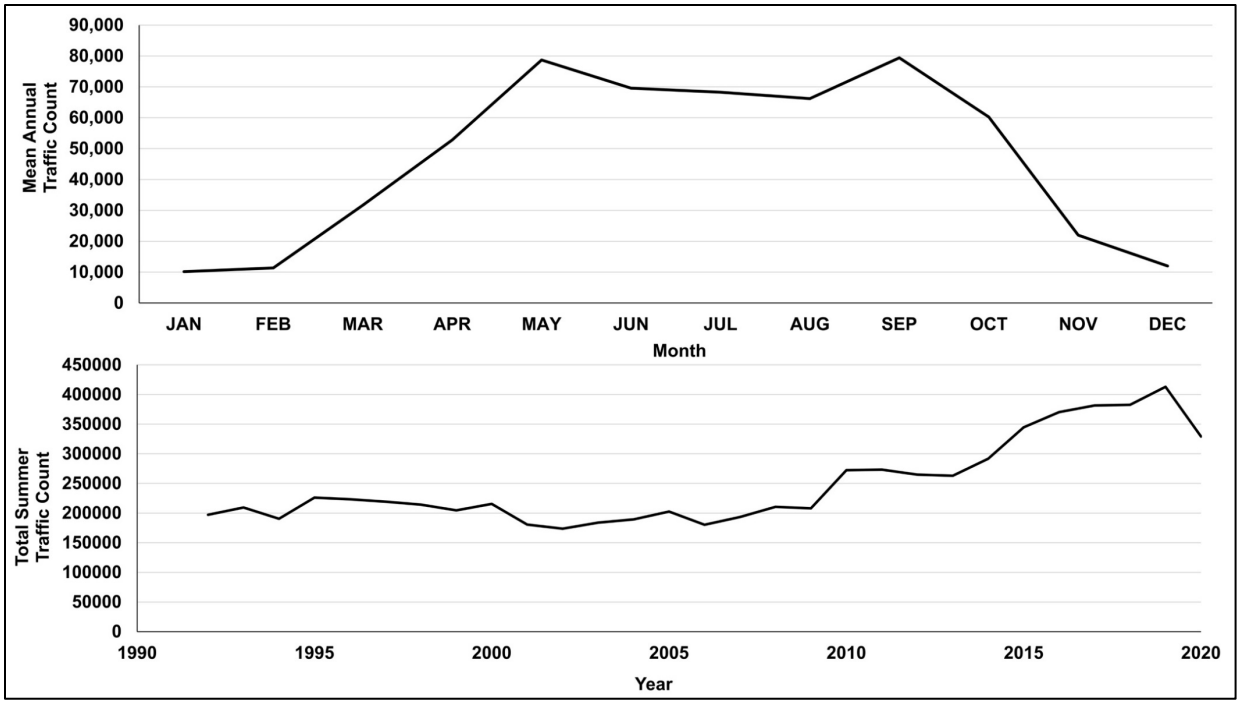


Figure 3.2.2-4. Mean (1992–2020) monthly traffic count data across the nine monitoring sites (top) and total summer (May–August) traffic count data for all nine monitoring sites (1992 to 2020) (bottom). Data credit: NPS Stats 2021a.

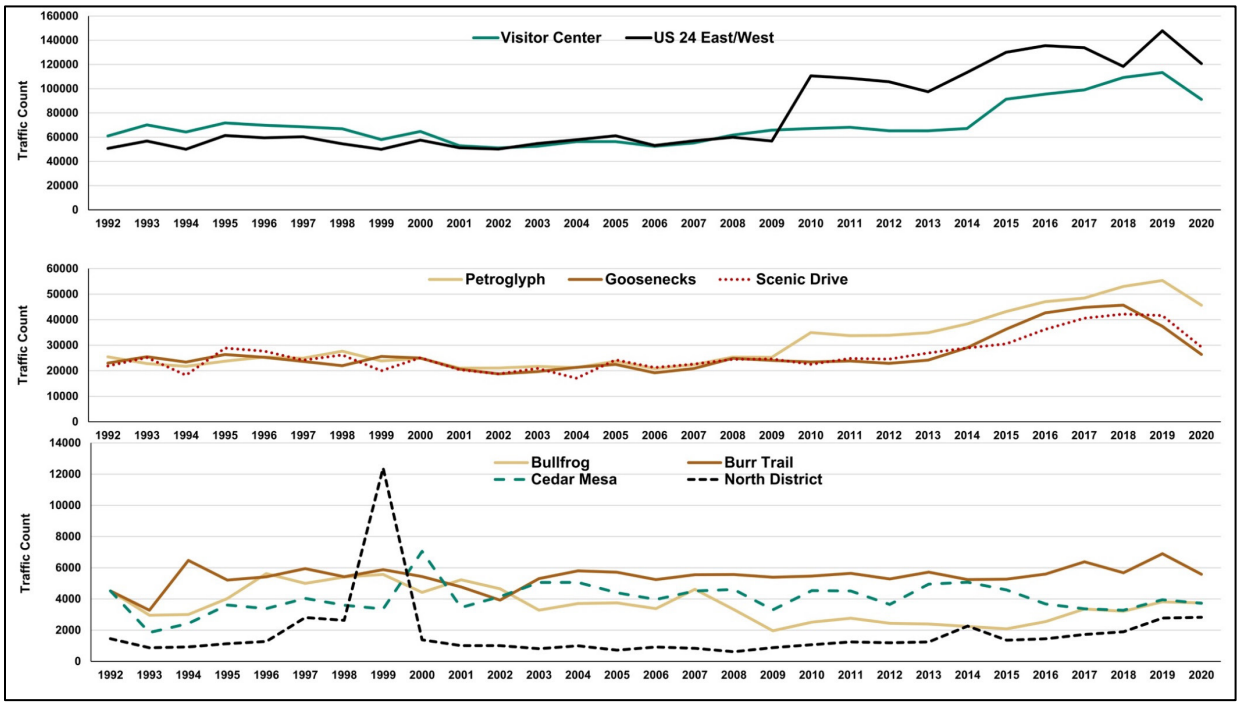


Figure 3.2.2-5. Total traffic count data (low to high from bottom to top) by site during summer (May–August) from 1992 to 2020. Data credit: NPS Stats 2021a.

Some of the increase in traffic may be attributed to changes in the way vehicles are counted at CARE. Since 2009, TRAFx Generation III counters were used at each of the locations (NPS Stats 2021a). From 1992 to 2008, inductive loop and seismic counters were used to track vehicles. Additionally, the raw count data were adjusted using different scaling factors to account for "in and out" traffic and "non-reportable" vehicles, which include those driven by NPS staff, volunteers, and researchers (NPS Stats 2021a). While differences in counting methods may explain some increase in apparent traffic, CARE's visitation (as in many parks) has increased substantially in recent years. From 2016 to 2019, CARE visitation exceeded one million annually (NPS Stats 2021a). More visitors are also spending time in the backcountry and front country campgrounds (NPS Stats 2021a).

3.2.3. Discussion

The NPS NSNSD furthers evaluates soundscapes using two measures of sound levels collected in the field (Table 3.2.3-1) (Turina et al. 2013). As described above, park staff collected acoustic data in the form of continuous digital audio recordings at three locations in CARE, but the data have not yet been analyzed. Field recordings can be compared to relative sound levels across sites and to identify noise sources (e.g., aircraft vs. vehicles) and natural sounds (e.g., water, wind).

Table 3.2.3-1. Proposed indicators and measures of condition for soundscape.

Indicator of Condition	Measure	Reference Criteria for Measure
Sound Level	% Time above reference sound levels	Most sound levels recorded at key points throughout the park are < 45 dBA, which is the World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund et al. 1999).
	% Reduction in listening area	Listening area is reduced by ≤ 30% over natural ambient sound levels.
Geospatial Model	L_{50} Impact	≤ 1.5 (Listening area is reduced by ≤ 30%).

Placement of CARE's three acoustic monitoring sites was driven by the need to understand more about traffic counts and the relative sound energy outputs of different vehicles (NPS, E. Brown, biologist, comments to draft assessment, 10 August 2021). The Cathedral Valley site is along an unpaved road in the semi-primitive zone. The Highway 24 site is in the road corridor zone on the primary paved road that bisects the park, which is embedded in the threshold management zone. Lastly, the Pleasant Creek site is located ~20 m (66 ft) from an unpaved road in the rural developed zone.

Measuring sound levels at other locations and zones in the park would be helpful in establishing baseline conditions and for informing planning activities in the future. For example, the repaving of the Scenic Drive is scheduled to occur within the next few years (NPS, S. Fritzke, superintendent, comments during NRCA manager-scientist meeting, 26 August 2021), and using noise-dampening surface materials may improve the acoustic environment along the drive or at least mitigate some of the noise associated with increased visitation.

When the park delineated the management zones, vehicle noise along backcountry roads was infrequent and not of management concern. Because visitor use and backcountry use, in particular, have increased, noise along backcountry roads may have also increased, potentially warranting additional monitoring (NPS 2018a).



Nature sounds at CARE include falling water at Two-story Ephemeral Waterfall, which forms when the ground cannot absorb the rain from monsoons quickly enough. Image Credit: NPS / EMILY VAN NESS.

CARE's foundation document (NPS 2018a) cites visual and noise distractions from recreational vehicles, overflow parking lots, and full campgrounds due to an increase in visitation as stressors to the park's soundscape. There is also a proposal to create a campground off the Burr Trail Switchbacks, which is included in a parcel owned by Garfield County, Utah, as well as a campground outside the park off Highway 24 (NPS, S. Fritzke, superintendent, comments during NRCA manager-scientist meeting, 26 August 2021). Although OHVs are not currently permitted in the park, the potential for use in the future is a management concern for which the park would like to be prepared.

Aircraft is also a source of noise and may be one of the primary sources in the backcountry (NPS 1998). There are seven vendors authorized to give an annual total of 284 air tours in CARE (Lignell 2020). In 2019, however, only one air tour occurred (Lignell 2020). But the possibility of a future increase in noise from air tours is possible. Private planes passing overhead, and military overflights also occur, but it is not currently possible to track the frequency of occurrence.

Some of these noise sources influence wildlife behavior, depending on noise level, proximity, and duration. For example, sudden and loud noises could displace the threatened Mexican spotted owl from roost or nest sites, making them more vulnerable to predators (USFWS 2012). While infrequent noise events are unlikely to cause long-term impacts, persistent noise may have negative effects on owls (USFWS 2012). And the canyon habitat that owls prefer in CARE may be more likely to amplify noises than other types of habitats (USFWS 2012).

Based on data published in Pater et al. (2009) and summarized in the U.S. Fish and Wildlife Service Recovery plan (USFWS 2012) for the spotted owl, "noises ≥ 80 dBO (decibels weighted for middle sound frequencies where owl hearing is the most sensitive), had a greater than 0.60 probability of causing an owl to flush. The sound metric used for this dose/response curve is 10-second owl-weighed Leq (i.e., equivalent continuous sound pressure level over a given period). This noise level is roughly equivalent to 69 dBA (i.e., decibels weighted for human hearing), or approximately as loud as an ordinary human conversation.

CARE staff recently began using sound monitoring equipment to determine owl occupancy in backcountry areas, and these recording devices may also be used to monitor the local soundscape around owl territories. According to the geospatial sound model, the highest existing median hourly sound level in CARE is expected to reach 67 dBA.

While there are few studies of the effects of noise and other types of human disturbance on desert bighorn sheep, Schoenecker and Krausman (2002) found that a variety of human disturbances, including noise, likely contributed to altered bighorn sheep behavior in Pusch Ridge Wilderness, Arizona. Low-flying, fixed-wing aircraft and helicopters caused behavioral changes in bighorn sheep, and their heart rates increased for one to three minutes following military overflights (Weisenberger et al. 1996). Frequent occurrences of noise sources, however, resulted in habituation and desensitization. In general, human predictability (e.g., staying on trails, camping in the same locations) reduces the effects of disturbance on wildlife as they become used to these types of disturbances (Papouchis et al. 2001).

In a review of CARE's study plan, one reviewer suggested that if songbirds (a natural component to the acoustic environment) declined because of their biophysical limits to water deficit, it could negatively impact the park's soundscape (NPS, D. Thoma, landscape ecologist, comments to draft NRCA study plan, 8 March 2021). This is supported by Albright et al. (2017), who found that desert songbirds in the southwestern U.S. are at greater risk of death on extremely hot days because of evaporative water loss. This is an example of how climate change can have far-reaching consequences beyond direct effects.

3.3. Springs, Seeps, & Tinajas (Gap Analysis), coauthored by Tyler Gilkerson

3.3.1. Background & Importance

Springs, seeps, and tinajas create unique habitats and represent rare sources of water throughout the otherwise arid CARE, supporting a host of endemic plants, relict plant species, and terrestrial and aquatic invertebrates (Springer et al. 2006). Many mammals also visit these resources for the water they provide. Furthermore, springs, which represent points of groundwater discharge, may serve as climate refugia as temperatures rise and surface water becomes less available (Cartwright et al. 2020). While springs can create groundwater-dependent ecosystems, tinajas are filled entirely by precipitation and snowmelt and tend to occur in developing ephemeral channels (Spence and Henderson 1993). Tinajas, also known as waterpockets, potholes, and pools, are depressions eroded into sandstone bedrock by water, wind, and/or chemical weathering processes (Spence and Henderson 1993). While smaller tinajas may dry out seasonally, larger tinajas can retain water year-round.



Ackland Spring West. Image Credit: NPS.

3.3.2. Status of Knowledge

Groundwater occurs in several major and minor aquifers throughout CARE. Due to their large thicknesses, areal extents, and/or observed yields to supply wells, the White Rim, Wingate, Navajo,

and Entrada sandstones are considered major aquifers (Blanchard 1986a; Hood and Danielson 1981; Marine 1962). While the White Rim Sandstone does not supply groundwater to any known park resources, the Wingate, Navajo, and Entrada sandstones support several CARE springs and seeps, and the Navajo Sandstone supplies groundwater to many wells surrounding the park.

The Carmel Formation, Salt Wash Member of the Morrison Formation, Ferron and Emery Sandstone members of the Mancos Formation, extrusive volcanic materials (e.g., Tertiary lava flows and tuff deposits), and unconsolidated sediments (e.g., Quaternary alluvium) are considered minor aquifers due to being relatively thin, having limited areal extents, and/or producing water of poor quality (Christiana and Rasmussen 1991; Hood and Danielson 1981). These aquifers are considered minor because they supply groundwater to a lesser number of CARE springs and seeps. Additionally, unconsolidated deposits have been targeted by many wells surrounding the park, especially to the west along the Fremont River Valley. The Moenkopi Formation can also be considered a minor aquifer as it sources all CARE drinking water and supplies groundwater to some wells west of the park.

Aquifers in the region receive most recharge either directly from precipitation, snowmelt, and/or streamflow (where streams cross unsaturated outcrops of permeable formations) or indirectly from infiltration through overlying permeable geologic materials (Blanchard 1986a,b; Cudlip and Kunkle 2004; Hood and Danielson 1981). Most of this recharge occurs in high-elevation areas (e.g., Thousand Lake, Boulder, and Henry mountains) and across areally extensive outcrops where fractured, unsaturated aquifer formations are exposed at the surface (e.g., Navajo Sandstone outcrops along the Waterpocket Fold) (Cudlip and Kunkle 2004). Direct recharge from precipitation decreases with elevation.

Based on the available data, there could be as many as 170 springs and seeps in CARE (Springer et al. 2006; Coles et al. 2009; USGS 2020a; SSI 2021). Most of these were reported in the park's vegetation map (Coles et al. 2009), which included 137 "park special" point features labeled as "springs and seeps mosaic" and "hanging gardens herbaceous vegetation" (Figure 3.3.2-1).

Tinajas were partially mapped by CARE staff, but Coles et al. (2009) also mapped tinajas as they were encountered while conducting plant surveys. To identify the areas in CARE that are likely to contain tinajas, we subset the NPS' geology geodatabase (Graham 2006) to include only Entrada Sandstone, Navajo Sandstone, and the Carmel Formation (Figure 3.3.2-1; Graham 2006, 2016), which occur in about 35% of the park. Those three formations, along with the Wingate Sandstone, account for 73% of the geologic strata associated with the occurrence of springs in CARE (Table 3.3.2-1, Figure 3.3.2-2a,b;).

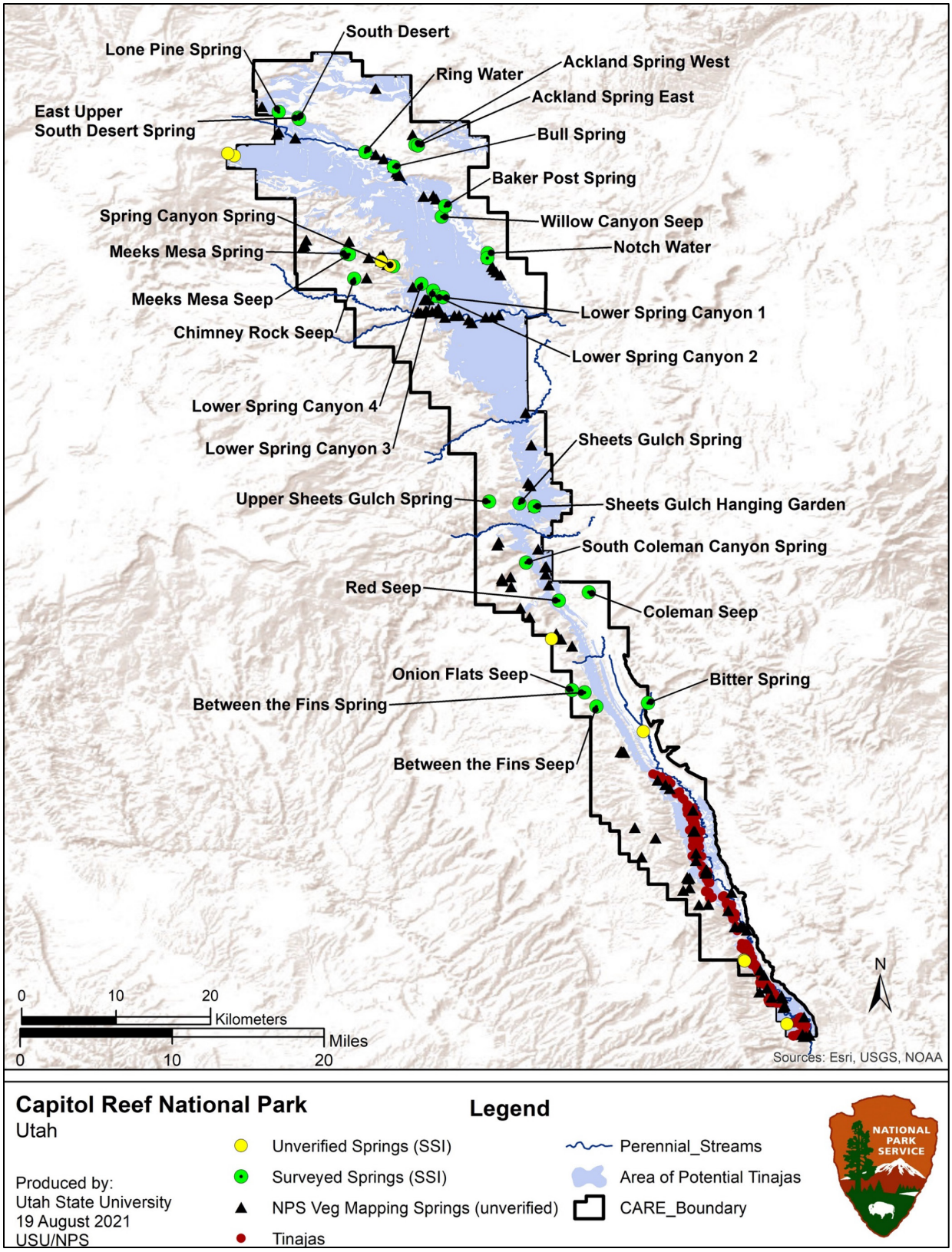
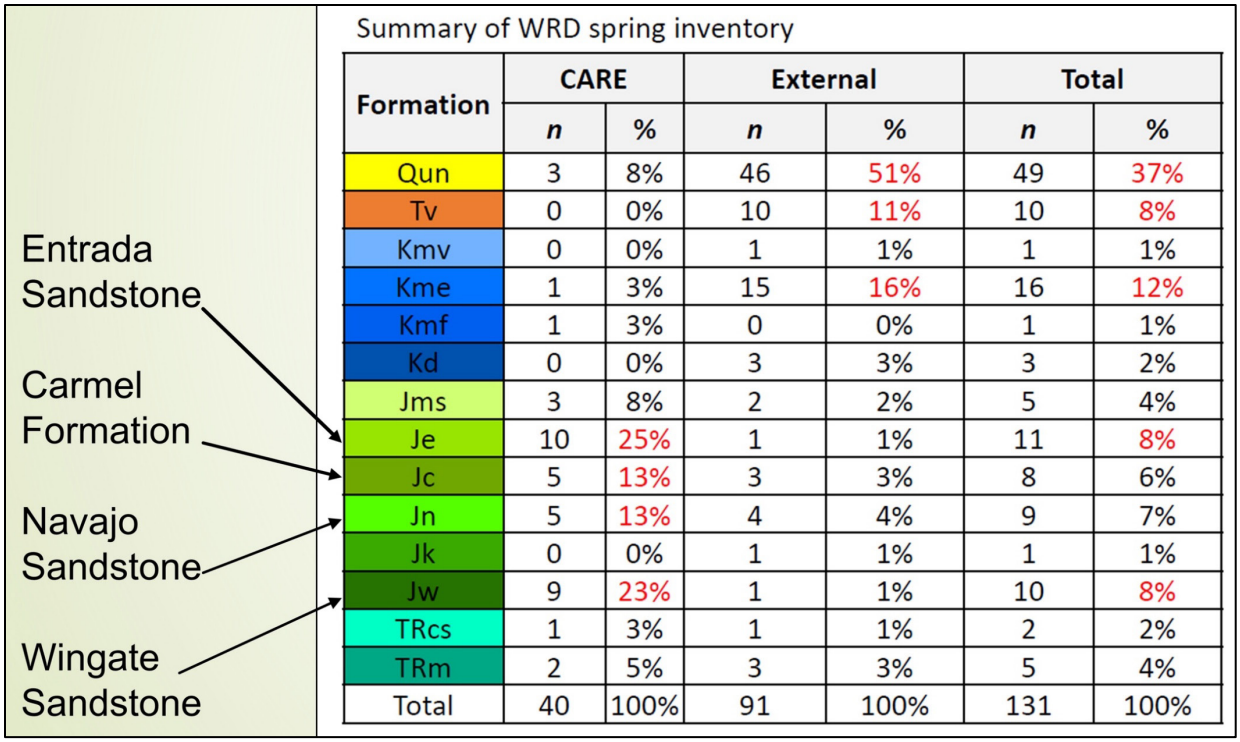


Figure 3.3.2-1. Locations of known springs and seeps, unconfirmed springs, seeps, and tinajas, and the area in CARE with the potential for supporting tinajas.

Table 3.3.2-1. Accessible version of information presented in Figure 3.3.2-2a, below. Summary of WRD spring inventory.

Formation	CARE		External		Total	
	n	**%**	**n**	**%**	**n**	**%**
Qun	3	8%	46	51%	49	37%
Tv	0	0%	10	11% [1]	10	8% [1]
Kmv	0	0%	1	1%	1	1%
Kme	1	3%	15	16% [1]	16	12% [1]
Kmf	1	3%	0	0%	1	1%
Kd	0	0%	3	3%	3	2%
Jms	3	8%	2	2%	5	4%
Je **(Entrada Sandstone)**	10	25% [1]	1	1%	11	8% [1]
Jc **(Carmel Formation)**	5	13% (1)	3	3%	8	6%
Jn **(Navajo Sandstone)**	5	13% [1]	4	4%	9	7%
Jk	0	0%	1	1%	1	1%
Jw **(Wingate Sandstone)**	9	23% [1]	1	1%	10	8% [1]
TRcs	1	3%	1	1%	2	2%
TRm	2	5%	3	3%	5	4%
Total	**40**	**100%**	**91**	**100%**	**131**	**100%**

[1] Highest percentages by formation, also shown shaded in gray.



Summary of WRD spring inventory

Formation	CARE		External		Total	
	n	%	*n*	%	*n*	%
Qun	3	8%	46	51%	49	37%
Tv	0	0%	10	11%	10	8%
Kmv	0	0%	1	1%	1	1%
Kme	1	3%	15	16%	16	12%
Kmf	1	3%	0	0%	1	1%
Kd	0	0%	3	3%	3	2%
Jms	3	8%	2	2%	5	4%
Je	10	25%	1	1%	11	8%
Jc	5	13%	3	3%	8	6%
Jn	5	13%	4	4%	9	7%
Jk	0	0%	1	1%	1	1%
Jw	9	23%	1	1%	10	8%
TRcs	1	3%	1	1%	2	2%
TRm	2	5%	3	3%	5	4%
Total	40	100%	91	100%	131	100%

Figure 3.3.2-2a. A summary of the primary geologic formations where CARE springs occur as compared to springs outside (external) of CARE's boundary. The highest percentages by formation are depicted in red. The springs by formation legend, shown in Figure 3.3.2-2b, corresponds to the information presented in this figure. Figure Credit: NPS / TYLER GILKERSON. The information shown in this figure is presented in Table 3.3.2-1, above.

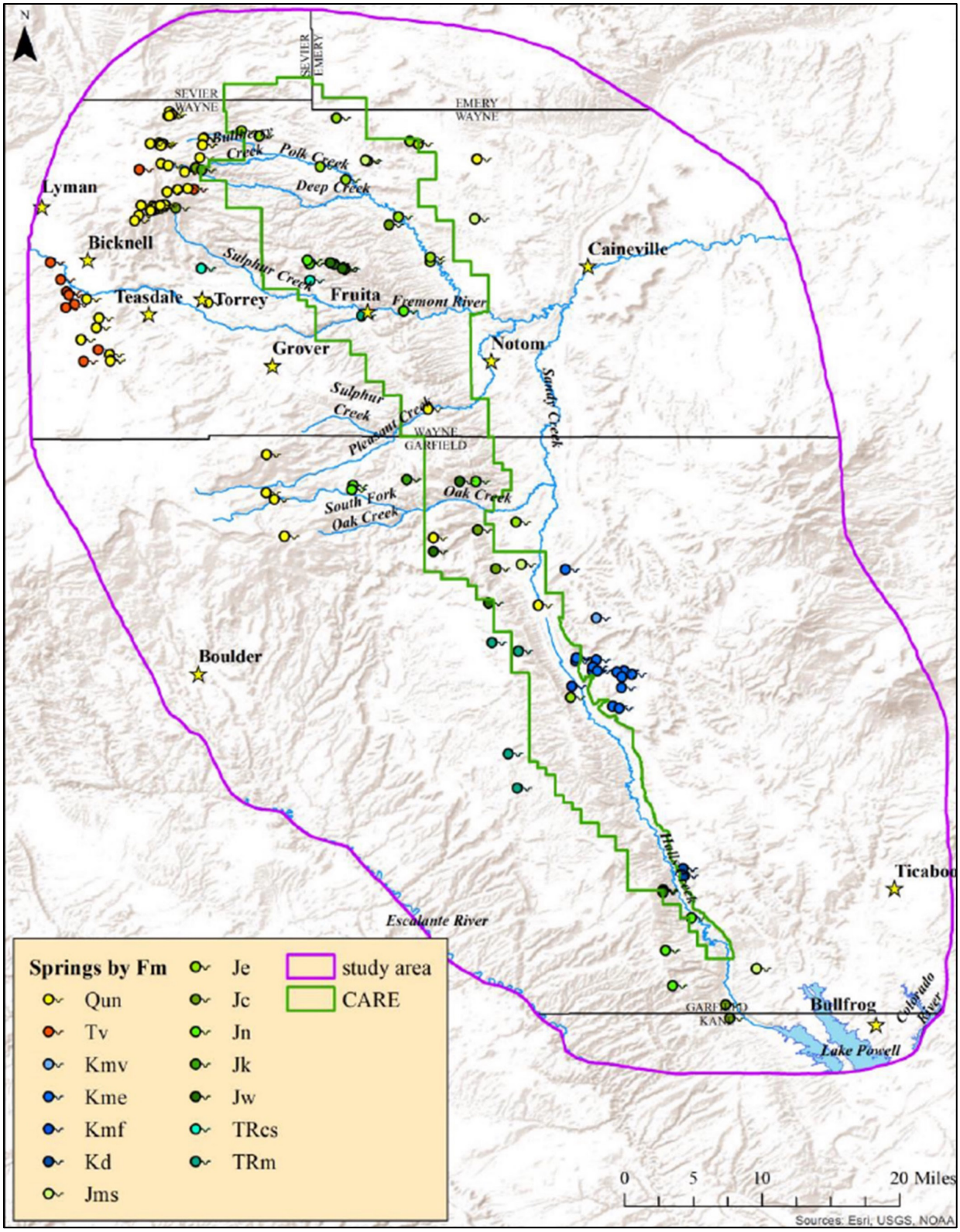


Figure 3.3.2-2b. Map of springs in and around CARE, color coded by associated geologic formation. The summary of springs and formations are shown in Figure 3.3.2-2a. Figure Credit: NPS / TYLER GILKERSON.

The regional hydrogeologic setting (e.g., hydrostratigraphy, existence of important geologic structures, and primary recharge areas for regional aquifers) largely determines spring locations, types, timing and magnitude of discharge, and water quality. The Springs Stewardship Institute's online database (SSI 2021) and the USGS National Hydrography data set (USGS 2020a) include a total of 38 mapped springs in CARE, nine of which require ground-truthing and 27 that were monitored by CARE staff in 2018 and 2019 using USFS' (2012) groundwater-dependent ecosystems protocol. Prior to the park's recent monitoring effort, the NCPN and the Southern Colorado Plateau Inventory & Monitoring Network inventoried springs in national parks throughout the region, which included six springs in CARE (Springer et al. 2006). In addition, earlier surveys of a limited number of springs and tinajas occurred in the 1990s (Baron et al. 1998; Berghoff 1995; Borthwick 1993; Christiana 1991; Fowler 1993; Fowler et al. 1995; Haefner and Lindahl 1991; LaFrancois 1996; and May et al. 1993).

Table 3.3.2-2 summarizes the available water quality data by spring (SSI 2021; Springer et al. 2006). Water quality data (i.e., discharge (mean flow) or presence of water if discharge could not be measured, water temperature, pH, and specific conductance) were collected at 18 springs, with repeat measurements at eight springs (Note: Meeks Mesa Seep did not have available data to summarize).

Water quality sampling occurred from 23–29 August 2005 (n = 4), 18 September to 3 October 2018 (n = 8), and 19 September to 22 November 2019 (n = 15). Discharge is related to spring type, in addition to source aquifer recharge areas and climate patterns, but sample sizes were not large enough to separate data by this factor or to make any generalizations about the condition of water quality of springs. Instead, we summarize the types of springs that are in CARE.

The 27 springs monitored by CARE staff are classified as hanging gardens (n = 3), hillslope (n = 4), hypocrene (n = 7), or rheocrene (n = 13). Hanging gardens occur where flow emerges horizontally along a cliff wall of a perched, unconfined aquifer (Springer and Stevens 2009). Hillslope springs occur on 30° to 60° slopes, with water often discharging from multiple, indistinct sources. Hypocrene springs are buried, and water does not reach the surface, usually because of very low discharge and high rates of evaporation and transpiration. Lastly, rheocrene springs emerge into one or more stream channels (Springer and Stevens 2009). Other spring types also likely occur in the park, but more surveys are needed to determine which types are present.

For plant richness at the 27 springs, observers reported at least 43 native plant species and 10 non-native plant species, but not all plants were identified to species. In addition, none of the species are endemic to the Colorado Plateau. Of the native species, only three are obligate wetland plants. Eight species are facultative wetland species. Another eight species are listed as facultative (i.e., occurs in both wetlands and uplands), five species are facultative upland (i.e., usually occurs in uplands) plants, and 18 species are upland species (i.e., almost always occurs in uplands) (USDA 2020).

Table 3.3.2-2. Summary of water quality data for springs and seeps surveyed in 2005, 2018 and 2019. Data credit: Springer et al. 2006 and SSI 2021.

Spring Type	Spring Name	Mean Flow (L/s) (SD)	Temperature (°C) (SD)	pH (SD)	Specific Conductance (SD)
Unknown	Ackland East	0.0072 (0.0021)	19.95 (1.48)	7.55 (0.09)	1321.5 (23.33)
Rheocrene	Ackland West	0.058 (0.008)	23.55 (2.62)	8.02 (0.57)	2007 (328.1)
Rheocrene	Baker Post	–	23.4	8.07	3999
Hillslope	Between the Fins	0.02 (NA)	18.71	6.92	2772.91
Rheocrene	Between the Fins Seep	–	11.3	8.59	3210
Rheocrene	Bitter	0.14 (NA)	19.8	8.01	3999
Rheocrene	Bull	0.115 (0.049)	15.3 (1.98)	7.49 (0.46)	3799.5 (282.14)
Rheocrene	Canyon	0.078 (0.080)	19.12 (2.38)	7.57 (0.7)	796.38 (61.4)
Hanging Garden	Coleman Seep	–	12	7.93	945
Hillslope	East Upper South Desert	–	–	8.41	1096.09
Rheocrene	Lower Canyon 2	–	–	7.87	388
Rheocrene	Lower Canyon 3	0.065 (NA)	–	7.27	606
Hanging Garden	Meeks Mesa Seep	–	–	–	Hypocrene
Rheocrene	Ring Water	0.23 (NA)	–	7.3	3999
Rheocrene	Sheets Gulch	–	–	7.42	2750
Rheocrene	South Coleman Canyon	–	–	8.04	3999
Hillslope	South Desert	0.0605 (0.01767)	–	7.89 (0.47)	1043 (4.24)
Rheocrene	Spring Canyon Spring	–	–	7.5	1965
Rheocrene	Upper Sheets Gulch	–	–	7.69	3999

The dominant native obligate and facultative wetland species at the 27 springs included narrowleaf (*Populus angustifolia*) and Fremont cottonwoods (*P. fremontii*), narrowleaf willow (*Salix exigua*),

and common threesquare (*Schoenoplectus pungens*). Tamarisk and cheatgrass (*Bromus tectorum*) were the two dominant, non-native plants observed (SSI 2021). For a complete list of the dominant plant species recorded at the 27 springs, refer to Appendix C, Table C-1.

The non-dominant native wetland species observed included chairmaker's bulrush (*Scirpus americanus*), longstem evening primrose (*Oenothera longissima*), scratchgrass (*Muhlenbergia asperifolia)*, reed canarygrass (*Phalaris arundinacea*), and Hooker's evening primrose (*Oenothera elata*). The non-dominant, non-native species included Russian olive, crested wheatgrass (*Agropyron cristatum*), redtop (*Agrostis gigantean*), and creeping bentgrass (*Agrostis stolonifera*). For a complete list of the non-dominant plant species recorded at the 27 springs, refer to Appendix C, Table C-2.

The disturbances observed at the park-monitored springs included hydrological, soil erosion, manmade structures, recreational, and animal, and one or more types of disturbance were observed at all 27 springs (SSI 2021). At least one measure of hydrological disturbance occurred at five springs; 25 springs exhibited at least some soil erosion; manmade structures were present at five springs; recreational disturbance occurred at two springs; and animal disturbance was present at seven springs. Livestock trailing and grazing was noted at 11 of the 27 springs, but recreational use was noted at only two springs; however, it can sometimes be difficult to attribute the source of a particular disturbance.

More remote springs may be more susceptible to human disturbance because of their importance to backcountry users. Popular backpacking routes that intersect with springs include Spring Canyon and Halls Creek; however, changing visitor use patterns may result in additional areas of impact.

The 2005 springs inventory (Springer at al. 2006) also included notes on disturbances at the six springs surveyed. Disturbances at West Ackland Spring included a road that crosses the spring in two places: at the outlet and about 100 m (328 ft) further downstream. The spring corridor is also used for cattle passage, with an estimate of 200 animals passing through in 2004, but the grazing allotment was retired in 2018. At East Upper South Desert Spring, a road and trail occur at the site, along with flow modifications for watering livestock. The spring is piped to a tank, but some water emerges downstream. Spring Canyon Spring was relatively intact when surveyed in 2005, with only light human disturbance. Disturbances at Chimney Rock Seep and Between the Fins Spring included flooding and moderate to moderately high past human disturbance.

As part of CARE's riparian habitat monitoring efforts, two springs in the Sandy 3 allotment were surveyed in 2015 and 2019/2020 using the USFS' Proper Functioning Condition protocol (Dickard et al. 2015). Bitter Spring Creek was evaluated in 2015 (Wagner et al. 2016) and in 2020 (NPS 2020b). Bitter Creek was evaluated in 2015 (Wagner et al. 2016) and in 2019 (NPS 2019). Both streams are supplied by perennial springs, and both spring ecosystems were considered "Functioning-At-Risk" in 2015 and 2019, in part due to livestock and native ungulate use.

Several other springs are also located along livestock trailing routes. These include both Ackland Springs along the Hartnet Trail; and Deep Creek Spring, Willow Canyon Seep, Baker Post Seep, and Notch Water Spring along the Lower South Desert Trail (NPS 2018b). In 2015, Ackland Spring No.

2 (west) and Deep Creek Spring were found to be in “Proper Functioning Condition,” but Notch Water Spring and Ackland Spring No. 1 (east) were found to be “Functional-At-Risk” (NPS 2018b).



Capitol Gorge tinaja, with a tadpole shrimp, which is one of many species specialized for a short life cycle in temporary pools of water, such as tinajas. Image Credits: NPS / JACOB FRANK.

Finally, a summary of the Palmer Hydrological Drought Index (PHDI) (NOAA 2021) is included in this gap analysis because it may be useful in predicting whether perennial tinajas transition to ephemeral tinajas, but more research is needed to link pool volume and drought indices, such as the PHDI. The PHDI “measures the hydrological impacts of drought (e.g., reservoir levels, groundwater levels, etc.) which take longer to develop and require more time for recovery. This long-term drought index was developed to quantify these hydrological effects, and it responds more slowly to changing conditions than the Palmer Drought Severity Index” (NOAA 2021).

Monthly PHDI data were obtained from the National Oceanic and Atmospheric Administration (NOAA) and averaged to derive annual averages for the state of Utah (NOAA 2021). The PHDI shows an average decline of 0.15/decade from 1895 to May 2021, although NOAA did not evaluate these data for trends (Figure 3.3.2-3). In general, negative values indicate dry conditions, while positive values indicate non-drought conditions. Seventeen of the last 21 years averaged a PHDI of less than −0.49, which is the lower threshold for normal conditions. In contrast, only seven years from 1979 to 1999 averaged a PHDI less than −0.49.

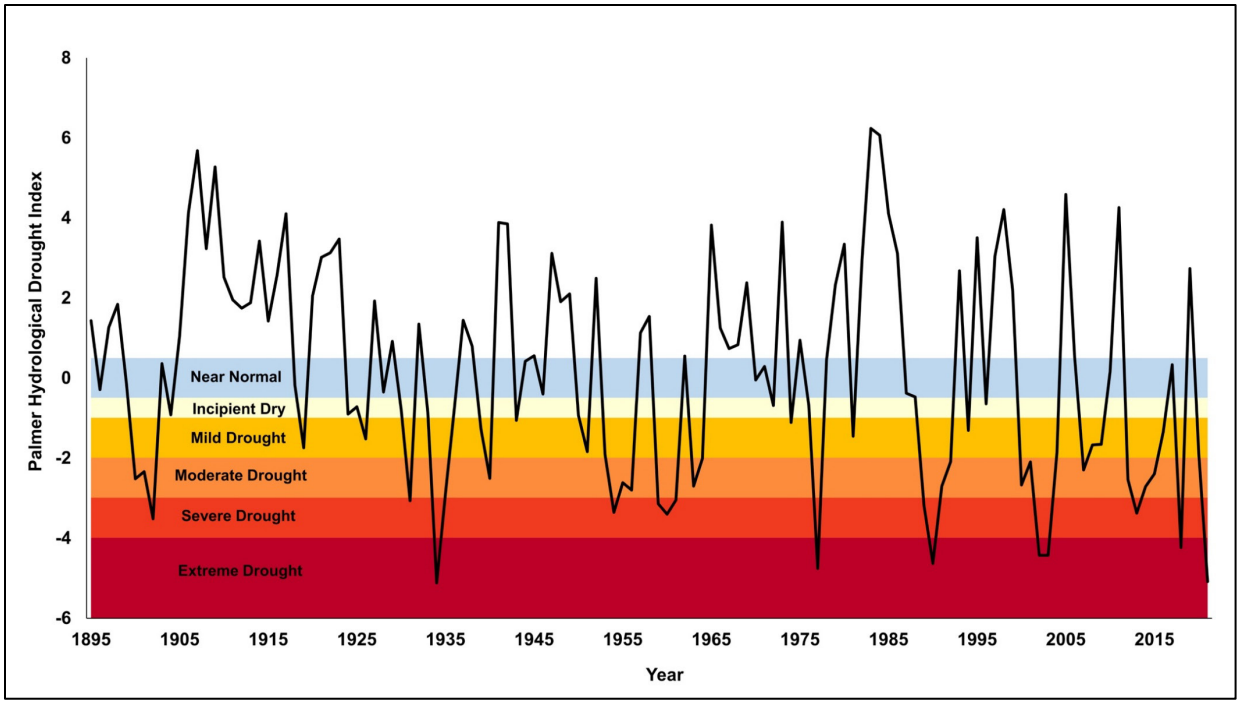


Figure 3.3.2-3. Annual Palmer Hydrological Drought Index (PHDI) across the state of Utah from 1895 to May 2021. Data credit: NOAA 2021.

3.3.3. Discussion

Table 3.3.3-1 includes a suite of indicators, measures, and reference criteria to consider for a future condition assessment of springs and seeps. These are based on the NCPN vital signs conceptual model and monitoring objectives for springs (Weissinger et al. 2017), in addition to other measures used in CARE's recent sampling efforts (e.g., disturbance).

The NCPN protocol (Weissinger et al. 2017) includes one measure of water quantity, four measures of water quality, and five measures of vegetation. In addition to discharge, we added PHDI to gauge the potential effects on tinajas. Because non-native species are a stressor, we included non-native plant richness and cover. Lastly, we included a measure of invertebrate and amphibian richness and abundance.

For the most part, these are also measures included in the groundwater-dependent ecosystems monitoring protocol (USFS 2012) that CARE staff currently use to monitor springs, except for non-native plant cover. Using the measures listed in Table 3.3.3-1 would allow for comparison to other springs in the network. Note that some measures in the table pertain to tinajas only.

Table 3.3.3-1. Proposed study details for springs, seeps, and tinajas. Data credit: Weissinger et al. 2017 and USFS 2021.

Indicator of Condition	Measure	Reference Criteria for Measure
Water Quantity	Discharge or wetted extent	No declines in discharge or no declines in wetted area or wetland plant extent if discharge data are unavailable. While discharge may vary seasonally, wetland plant extent is more constant unless there are declines in discharge.
	Palmer Hydrological Drought Index (PHDI) (tinajas only)	≥ −0.49 (near normal to extremely wet).
	Tinaja pool volume	Perennial pools remain perennial and most ephemeral pools fill seasonally.
Water Quality	pH	No reference criteria are available.
	Specific conductance	No reference criteria are available.
	Temperature	No reference criteria are available.
	Fecal coliform concentration	Utah Division of Water Quality standards that are relevant for backcountry users.
Vegetation	Native species richness	Total and average richness per spring is comparable to other springs and tinajas on the Colorado Plateau. Native species are well represented across springs and tinajas.
	Native species cover	Native species dominate cover (>95%) of plants in the defined area of springs and tinajas.
	Wetland species richness	Total and average richness per spring is comparable to other springs and tinajas on the Colorado Plateau. Wetland species are well represented across springs and tinajas.
	Wetland species cover	Wetland species dominate the defined spring area, but upland plants sometimes occur.
	Non-native plant richness	No non-native plants or fewer than 3 species are present that are not considered invasive.
	Non-native plant cover	Non-native plant cover is <5% for non-invasive species and <1% for invasive species.
Disturbance	Type and degree	Disturbances are natural rather than human-caused, and if human-caused, disturbance is such that it does not alter/affect spring or tinaja function.
Community Composition and Richness	Richness and abundance of aquatic life (amphibians and invertebrates)	Species representative of taxa are commonly found in undisturbed springs, seeps, and tinajas.

Because discharge varies greatly by spring and season, we used a reference criterion of no declines in discharge. Notably, seeps with no measurable discharge are some of the most common spring types in network parks (Springer et al. 2006), which is why the alternative measure of wetted extent or extent of wetland plants can serve as a proxy for discharge. However, it is unlikely that water quantity and quality of CARE springs, seeps, and tinajas can be assigned conditions due to the lack of repeat measurements and the absence of state standards of water quality for spring ecosystems.

Standards, which can be developed through consultation with area experts, will depend on CARE management objectives (i.e., suitability for wildlife health, backcountry users, or some other criteria) (NPS, T. Gilkerson, hydrogeologist, comments to draft evaluation, 14 July 2021). There are no reference criteria for spring vegetation, so we developed qualitative statements that can be compared to data from other parks on the Colorado Plateau.

Because springs and seeps are sourced with groundwater, they can be more resilient to the effects of climate change than surface water-dependent systems (Cartwright et al. 2020). However, their degree of resilience depends largely on groundwater residence times, which can vary from days to centuries or longer (Solder et al. 2016). Springs supplied by groundwater with long residence times are more likely to serve as climate refugia in arid regions, but excessive groundwater extraction from source aquifers can negate resiliency. One study found that groundwater discharge at eight of 19 springs sampled in the Upper Colorado River Basin responded to drought in as little as six months (Solder et al. 2016). This suggests that groundwater residence times may be relatively short for some springs in the region, with response times on the order of decades or less. This is supported by a study of spring discharge response to climate change in Arches National Park (ARCH). Weissinger et al. (2016) found that spring discharge for two springs responded to reductions in 10-year cumulative winter precipitation.



Citizen scientists collecting dragonflies, which may serve as indicators of water quality, including the presence of mercury. Image Credit: NPS Air Resources Division, Dragonfly Mercury Project.

In the Upper Colorado River Basin, 98% of water for agriculture and municipal use comes from surface water, while the remaining 2% comes from groundwater (Maupin et al. 2018). However, as surface water declines and the need for water increases, there is likely to be more pressure on aquifers (Maupin et al. 2018). Therefore, understanding groundwater recharge areas and residence times associated with source aquifers for CARE springs and seeps is critical for predicting the health of these groundwater-dependent resources.

In contrast to springs and seeps, tinajas are entirely dependent on precipitation. While smaller tinajas may dry out seasonally, larger tinajas can retain water for several weeks, months, or years depending on size (Spence and Henderson 1993). Some of the larger, perennial tinajas support riparian plants (Heil et al. 1993; Spence and Henderson 1993; Spence 1996). Based on Baron et al. (1998), in CARE's Waterpocket Fold, tinaja pool volume may range from a few liters to more than 1,000 m^3 (35,315 ft^3), with sediment depths up to 2.0 m (6.5 ft). Pools with volumes greater than 90 m^3 (3,178 ft^3) are usually perennial unless they are shallow (0.4 m [1.3 ft]) or there is a prolonged drought (Haefner and Lindahl 1991). A study of 463 pools at CARE found that water volume ranged from 0 m^3 to 1,532 m^3 (54,102 ft^3), with a mean volume of 21 m^3 (742 ft^3), but most pools were 15 m^3 (530 ft^3) or less (Baron et al. 1998). This suggests that most pools in CARE are ephemeral.

The amount of water collected in perennial pools and the length of time ephemeral pools retain water depends on the amount and frequency of precipitation, pool volume and dimensions, substrate permeability, and rates of evaporation. The degree of shading, wildlife demands (e.g., transpiration), and the permeability of host geologic materials also influence how long tinajas remain filled. In a study of tinajas in CARE, Berghoff (1995) found that most tinajas are shaded for at least part of the day; only 26% of tinajas were entirely exposed to sun throughout the day. Berghoff (1995) also found that vegetation was a key indicator of water permanence for tinajas in CARE (Berghoff 1995). Even if water appeared absent in a pool, the presence of vegetation suggested the presence of subsurface water. Pools with vegetation lost water faster than pools without vegetation due to evapotranspiration, but vegetation also provided shade (Berghoff 1995). At tinajas where plants occurred, diversity was high, particularly at deep pools shaded by rock (Spence and Henderson 1993). In some cases, tinaja plant diversity can be higher than in smaller hanging gardens; however, larger hanging gardens are known as biodiversity hotspots (Spence and Henderson 1993).

Spence and Cushing (2019) formulated four potential climate change response scenarios for spring ecosystems in the adjacent GLCA. The main assumption in all four scenarios is that discharge will decline due to reduced snowpack and warmer temperatures, but over what time period remains uncertain. If aquifer declines are slow, then springs are likely to remain stable in the short-term but may eventually exhibit effects on vegetation as water becomes less available. At the other extreme, a rapid decline in discharge may result in the collapse of spring ecosystems (Spence and Cushing 2019). However, variability in microclimates across spring areas may ameliorate climate change effects.

Weissinger et al. (2016) recommended "prioritizing deeply shaded, north-facing, and/or higher-elevation springs for protection and restoration." These springs are likely to be more resilient to increases in temperature. In addition to the microclimate characteristics suggested by Weissinger et

al. (2016), Cartwright et al. (2020) include consistent discharge, long groundwater residence times, and few localized threats from disturbances, among other characteristics as important in evaluating a spring's ability to serve as a climate refugium. Additionally, changes in potential evapotranspiration and pond evaporation with changing temperatures may alter the water balance of spring and tinaja systems in the park (NPS, D. Thoma, landscape ecologist, comments to draft study plan, 2 March 2021).

Although human and animal disturbances are of concern, natural disturbances, such as rock fall, fire, erosion (natural or otherwise), and flooding are also potential drivers of spring ecosystem structure and function (O'Dell et al. 2005). Encroachment by non-native species, such as Russian olive and tamarisk, may outcompete native plant species, which is especially concerning for those species that only occur at springs.

Lastly, airborne or atmospheric contaminants, such as heavy metals or nitrogen fertilization, could impact the quality of springs and seeps. For example, CARE ranked 7th highest of 100 national parks sampled for mercury in dragonfly larvae, which can serve as sentinels of wetland health (Eagles-Smith et al. 2020). Moreover, from 2009 to 2011, airborne mercury in the Four Corners region of New Mexico, Colorado, Arizona, and Utah, was particularly high relative to other areas in the U.S., especially during spring and summer. New regulations implemented since these studies may reduce mercury pollution (Sather et al. 2013). As previously described, springs and seeps may transport pollutants to surface waters, some of which may be deposited through atmospheric deposition and leached into aquifers (O'Driscoll et al. 2019).

3.4. Riparian (Gap Analysis)

3.4.1. Background & Importance

Riparian plants provide habitat for a multitude of species, supplement floodplain diversity and complexity, add channel stability, and provide shading of streams by overhanging vegetation, which reduces stream temperature and provides cover for fish and other aquatic species. Riparian plant communities in the park range from marshes dominated by grasses and sedges, stream-side facultative wetland species such as willow (*Salix* species), and deciduous forests, which include water-dependent woodlands and shrublands. Riparian woodlands occur in floodplains, tributary canyons, and below pouroffs (Coles et al. 2009). This habitat type occurs along the perennial streams in CARE and includes Sulphur Creek, Pleasant Creek, Oak Creek, Polk Creek, and Halls Creek (Coles et al. 2009). Spring Canyon and Sheets Gulch also contain flowing water in some sections during most years (Coles et al. 2009). Note that Polk Creek may be more of an intermittent stream with springs and seeps flowing into the channel than a perennial stream (NPS, C. Livensperger, plant ecologist, comments to draft assessment, 7 September 2021).



Fall colors along the Fremont River. Image Credit: NPS / ANN HUSTON.

3.4.2. Status of Knowledge

The six perennial streams flowing through the park are the focus of this gap analysis (Figure 3.4.2-1). Although there are many reports and data sources describing various aspects of riparian function in

the park, riparian systems are complex (see the NCPN's conceptual model [O'Dell et al. 2005, Appendix A-2] for riparian and aquatic systems), and data are available for only portions of some streams with many spatial and temporal data gaps. The data summaries include stream discharge, water quality, plant composition and structure, groundwater, channel geomorphology, and plant health.

There are U.S. Geological Survey (USGS) stream discharge data for the Fremont River, Pleasant Creek, and Sulphur Creek, but few current data are available (UGSG 2021). Data include peak discharge for Sulphur Creek from 1959 to 1974 (Site ID 09330120); Sulphur Creek peak discharge from 1959 to 1965 located outside the park boundary (Site ID 09330100); Pleasant Creek peak flow data from 1959 to 1973, also located outside the park boundary (Site ID 09330200); Pleasant Creek annual discharge from 1969 to 1972 (Site ID 09330210); and Fremont River annual discharge from 1986 to 2011 (Site ID 09330230) (USGS 2021).



Sulphur Creek. Image Credit: NPS.

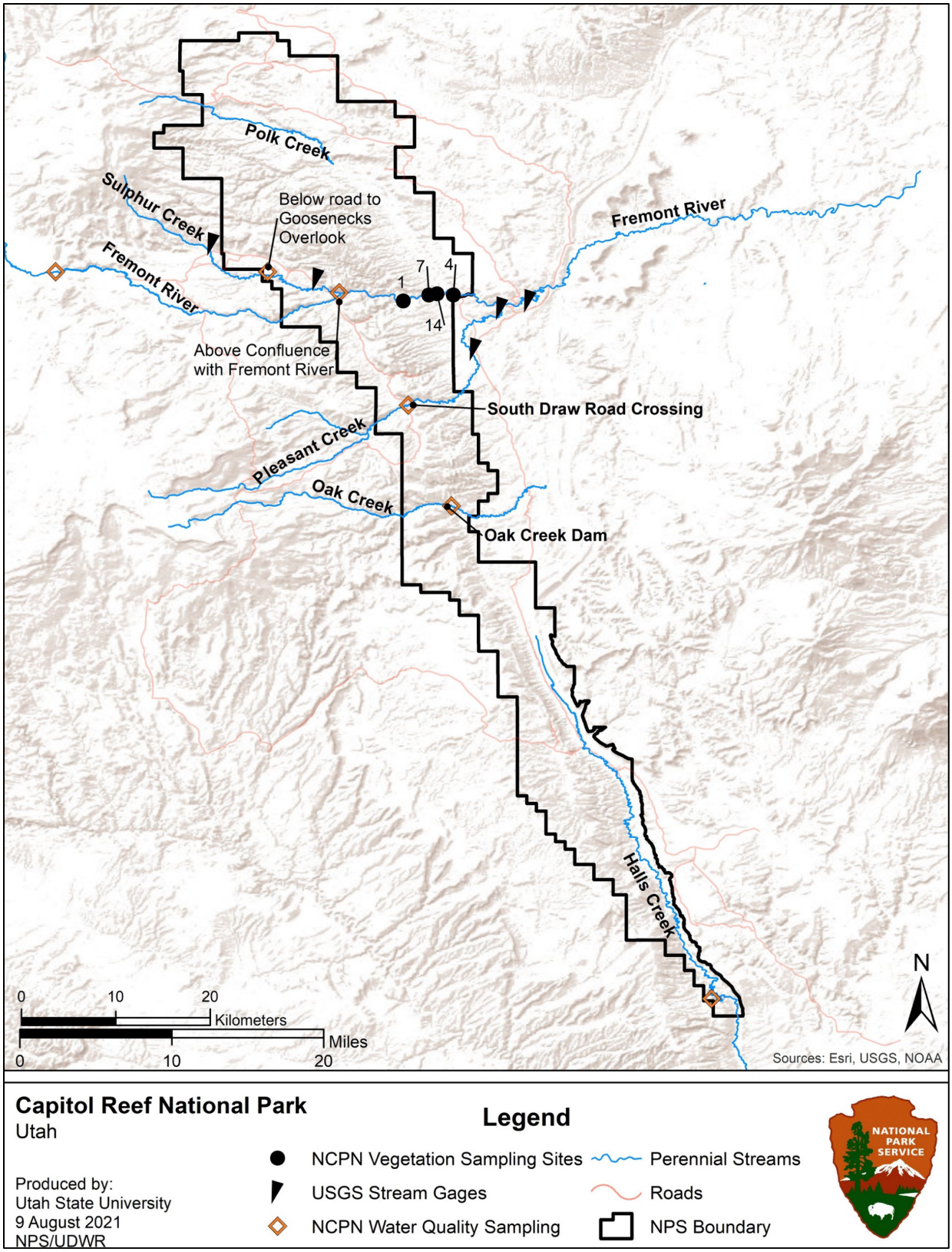


Figure 3.4.2-1. Locations of perennial river and creeks, vegetation, water quality, and water flow monitoring sites in and just outside of CARE.

The NCPN has also collected flow data and water quality data at five sampling sites. The sites are Halls, Oak, and Pleasant creeks, and two locations on Sulphur Creek (NPS, R. Weissinger, aquatic ecologist, data file to Lisa Baril, Utah State University, 24 August 2021). NCPN flow data from the five water quality sampling sites were collected during most months, beginning in 2006 to 2020 (Table 3.4.2-1). Across all five sites, most flow measurements recorded were within the "Normal" range (Figure 3.4.2-2). For Halls Creek, no measurements were "Dry" or "Low." Oak Creek was the only site that exhibited values in the "Dry" category. This site also exhibited the highest proportion of measurements in the "Low" flow category.

Table 3.4.2-1. Summary of flow data collected at five NCPN water quality sampling sites.

Location	Years
Halls Creek below the Narrows	2006–2008, 2014–2016, 2018–2020
Oak Creek above Sandy Ranch Dam	2010–2014, 2016–2018, 2020
Pleasant Creek south of Sleeping Rainbow Ranch	2008–2010, 2012–2014, 2016–2018, 2020
Sulphur Creek above Confluence with Fremont River	2008–2010, 2013–2020
Sulphur Creek below Goosenecks Overlook	2008–2012, 2014–2020

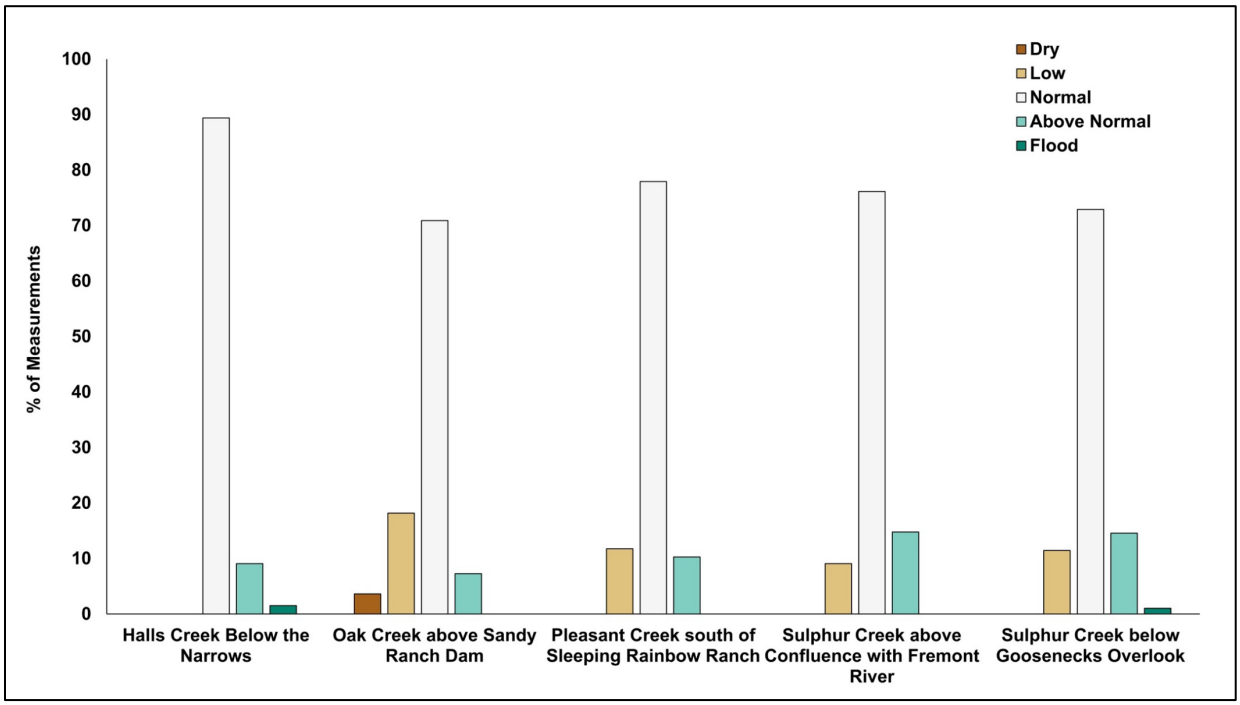


Figure 3.4.2-2. Results of NCPN flow measurements (2006–2020) at the five sampling sites. Data credit: NPS, R. Weissinger, aquatic ecologist, data file to Lisa Baril, Utah State University, 24 August 2021.

For the Fremont River, the NPS' Water Resources Division (WRD) hydrologist, Chris Gable, developed stage discharge estimates based on water level loggers installed and maintained by the NCPN. The estimated record begins 19 January 2011 and runs through 2020 (but from 2011 to 2014,

data were not collected during all months). Mean annual and mean monthly metrics were summarized by NCPN staff (R. Weissinger, aquatic ecologist) and sent to USU staff 22 July 2021. Note that the data presented in this assessment from that effort are provisional.

From 1968 to 2011, mean annual discharge (73.4 cfs) at the USGS Fremont River gaging station remained stable (F (42) = 0.30, p = 0.59, R^2 = 0.01), fluctuating between a low of 52.6 cfs in 2009 to a high of 133 cfs in 1985 (Figure 3.4.2-3). Note that from 1983 to 1988, discharge was elevated relative to the period of record.

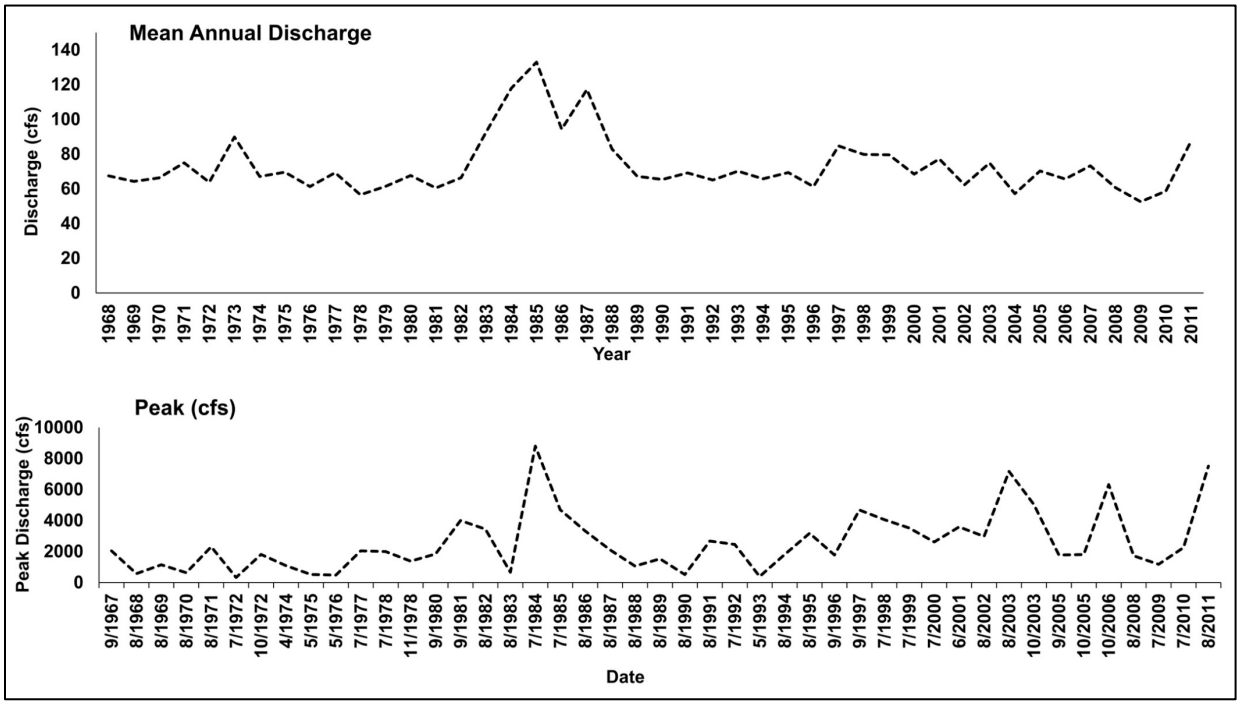


Figure 3.4.2-3. Mean annual discharge (top, from 1968 to 2011) and peak annual discharge (bottom, from 1967 to 2011) for the USGS Fremont River stream gage. Data credit: NPS, R. Weissinger, aquatic ecologist, data file to Lisa Baril, Utah State University, 24 August 2021 and Chris Gable, with NPS WRD, developed the stage discharge estimates.

While there is large variability, there was a slight but significant increase in peak annual discharge from 1967 to 2011 (F (43) = 11.85, p = 0.001, R^2 = 0.22). Although peak discharge occurred in July or August, mean monthly flow was highest from February through March and lowest in May through July (Figure 3.4.2-4, top). This pattern is typical of low elevation streams in the Southwest that are supplied by spring snowmelt in the headwaters and a brief, but intense, late summer monsoon season. Spring peak flow may also be at least partially attributed to low levels of plant transpiration relative to summer months and the fact that water has not yet been diverted for irrigation (NPS, D. Witwicki, NRCA project manager, comments to draft assessment, 19 August 2021).

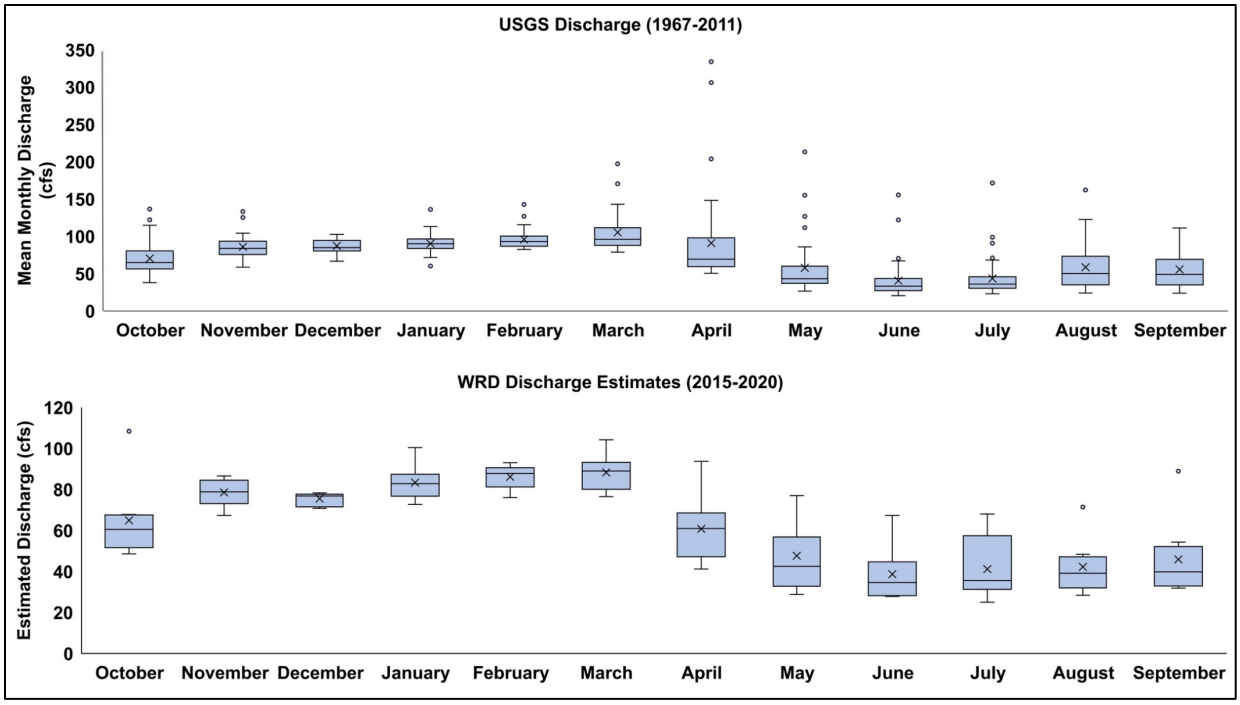


Figure 3.4.2-4. Boxplots of monthly discharge for the USGS Fremont River stream gage (1967–2011) (top) and WRD estimated discharge (2015–2020) (bottom). Top data credit: USGS 2021. Bottom data credit: NPS, R. Weissinger, aquatic ecologist, data file to Lisa Baril, Utah State University, 24 August 2021 and Chris Gable, with NPS WRD, developed the stage discharge estimates.

The WRD estimate for mean annual discharge from 2015 through 2020 was 58.85 cfs (Figures 3.4.2-4 bottom and 3.4.2-5), which is lower than the 1967–2011 mean annual discharge (73.4 cfs) provided by the USGS. When excluding USGS data from 1983 to 1988, mean discharge was still higher, on average, (68.24 cfs) than WRD's more recent estimate. These differences may be due to the locations of the USGS stream gage vs. the NCPN data loggers used to build the discharge model (the Fremont River gage was downstream of the junction with Pleasant Creek, while NCPN's reach is upstream).

The WRD mean discharge estimate (58.85 cfs) is slightly lower, but similar, to the mean of reconstructed flows produced by Auble et al. (2005) for the Fremont River in CARE for 1968 to 1996 (62.2 cfs). Like USGS data, WRD estimates also show that mean flows were highest in February and March, declining through July, with increasing flows from August through October (Figure 3.4.2-4, bottom). Mean monthly discharge was consistently lower for the WRD estimates than for the USGS stream gage data, with differences ranging from 30.18 cfs in April to 1.83 cfs in June.

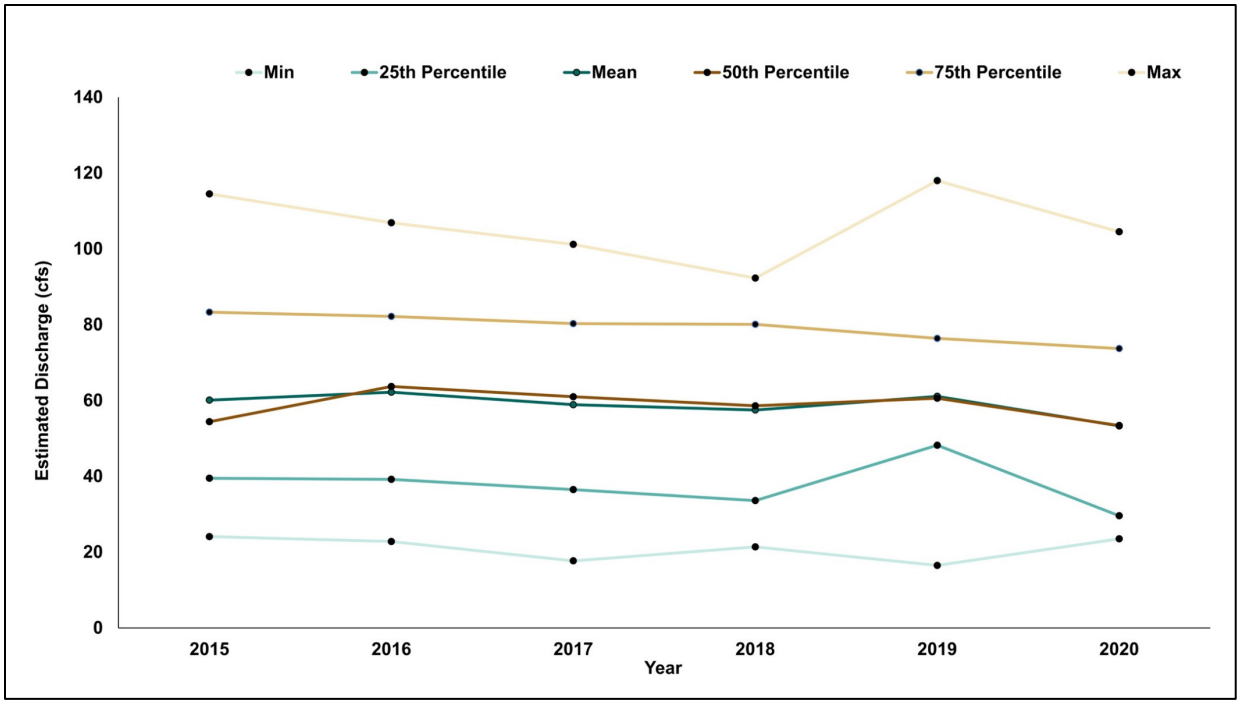


Figure 3.4.2-5. WRD estimates of Fremont River discharge from 2015 to 2020. Data credit: NPS, R. Weissinger, aquatic ecologist, data file to Lisa Baril, Utah State University, 24 August 2021.

Similar to monthly flow, depth to alluvial groundwater along the Fremont River follows a cyclic pattern (daily data from January 2011 to July 2020 were collected by NCPN staff and downloaded by Utah State University from the Aquarius web portal on 9 February 2021) (NPS 2020c). The water table was shallowest in January through March, with a gradual increase in depth to groundwater occurring from April through August (Figure 3.4.2-6).

Depth to groundwater is critical for the establishment and maintenance of woody riparian vegetation, such as cottonwood and willow. Alluvial groundwater of ≤2 m (≤6.6 ft) is thought to support the establishment of cottonwood seedlings, while <4 m (<13.1 ft) is necessary to maintain mature trees (Stromberg et al. 1996). Although all depth to groundwater data were more than adequate for maintaining mature riparian trees, and very close to the requirement for tree seedling establishment, there has been a slight, but significant, increase in depth to groundwater (averaged for both sides of the river) during the growing season since 2014 (F (30) = 16.33, p = 0.0003, R^2 = 0.35).

A subset of water quality measures (i.e., dissolved oxygen, temperature, contaminants of emerging concern, mercury) were evaluated in the fishes assessment of this report (see report section 3.11 for more details). In this gap analysis, we only reported the percentage of water samples that exceeded Utah Division of Water Quality standards (UDWQ 2020a) for total dissolved solids, nitrogen, phosphorus, *Escherichia coli* (*E. coli*), and pH in the rivers and streams sampled at CARE by the NCPN. In addition, we also reported streams listed as impaired by UDWQ (2020b) within the watershed units that overlap with CARE.

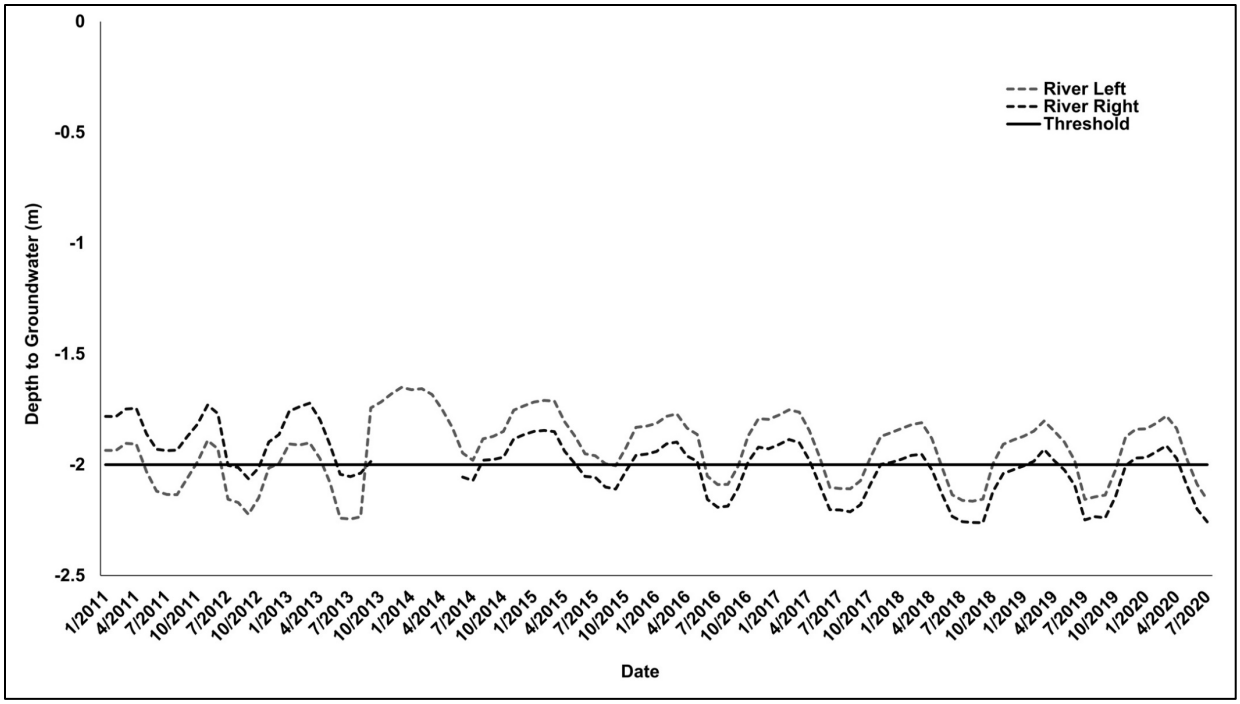


Figure 3.4.2-6. Monthly depth to alluvial groundwater at NCPN monitoring sites along the Fremont River from January 2011 to July 2020 shown with the threshold required for cottonwood seedling establishment. Data credit: daily data from January 2011 to July 2020 were collected by NCPN staff and downloaded by Utah State University from the Aquarius web portal on 9 February 2021.

Brown and Thoma (2012) reported elevated nutrient concentrations (phosphorus and nitrogen) for the Fremont River before it flows into the park at a site near Bicknell, Utah west of CARE, but there was an overall downward trend in the percentage of samples that exceeded UDWQ standards from 1977 to 2003. Phosphorus, however, continues to exceed UDWQ (2020a) standards at streams sampled in the park (nitrogen is not currently collected by NCPN) (Figure 3.4.2-7).

Similarly, total dissolved solids exceeded standards for some sites in multiple sampling periods, particularly in Sulphur Creek (Figure 3.4.2-8). UDWQ (2020b) also considers the Fremont River and tributaries, which include Sulphur Creek, from the east boundary of CARE to Bicknell, Utah as impaired for total dissolved solids for the most recent (2018/2020) evaluation period (Table 3.4.2-2). Pleasant and Oak creeks were impaired for temperature while Halls Creek was not impaired for any variable (UDWQ 2020b).

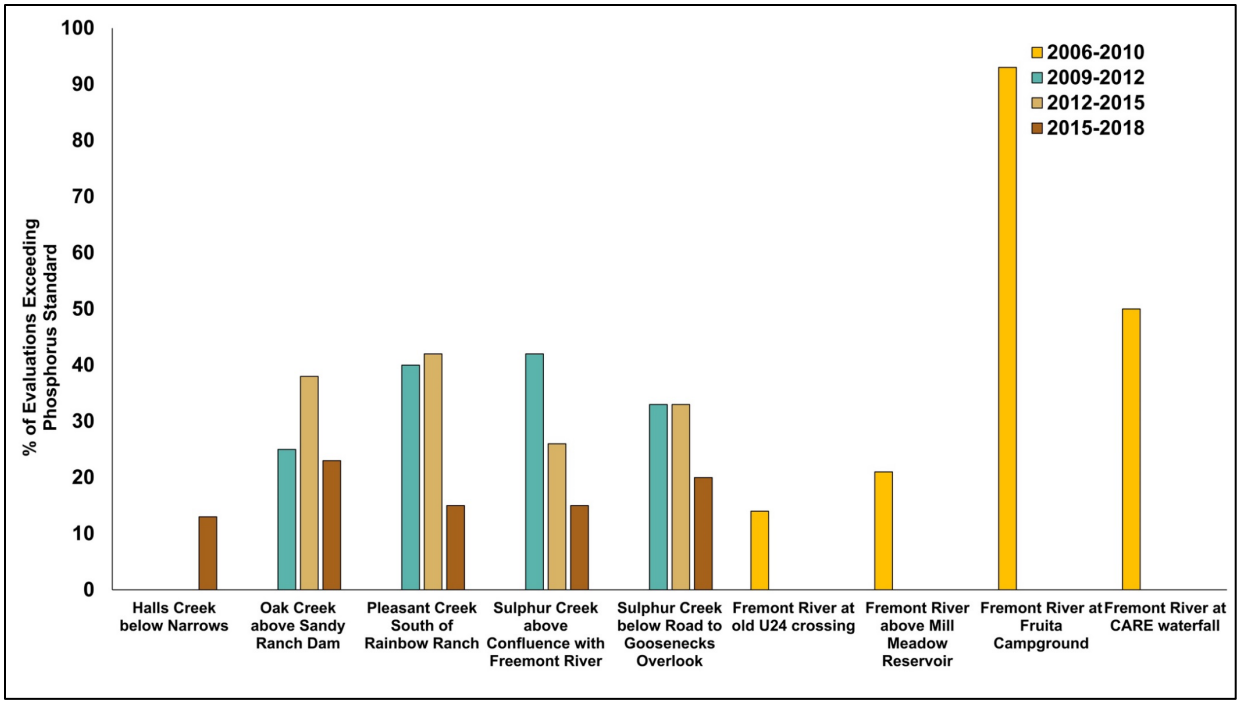


Figure 3.4.2-7. Percentage of NCPN water samples exceeding phosphorous standards by perennial stream.

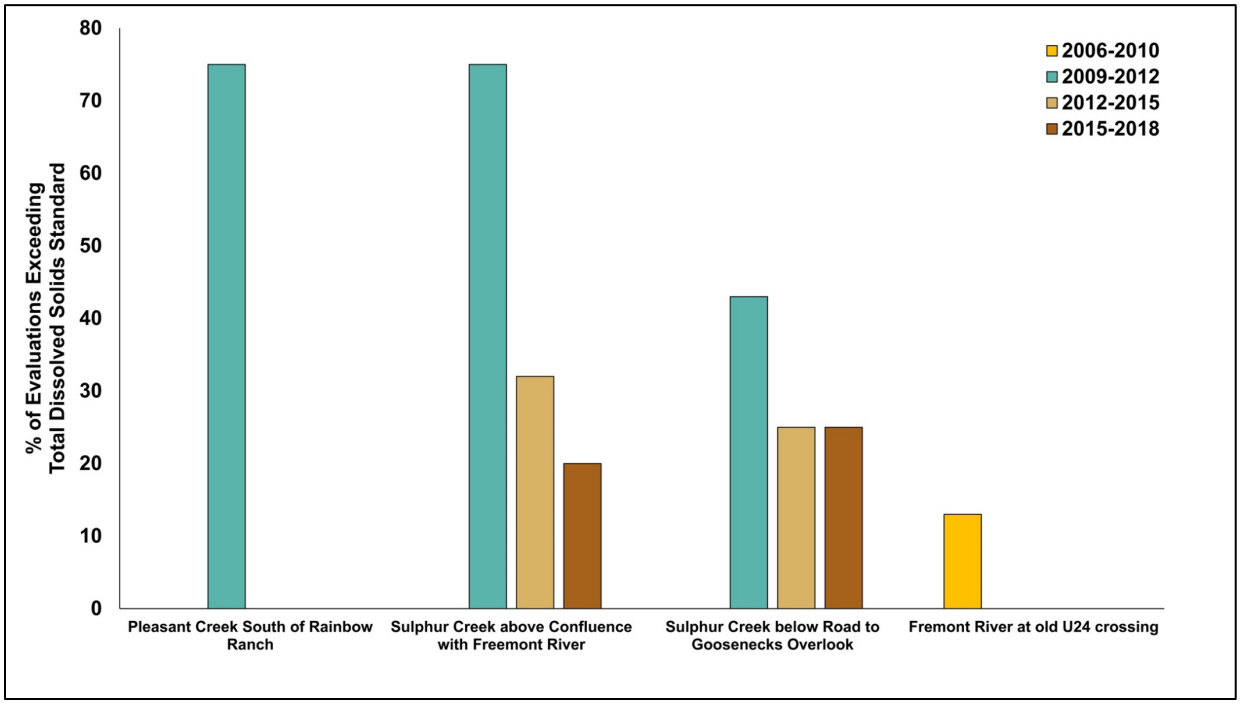


Figure 3.4.2-8. Percentage of NCPN water samples exceeding the total dissolved solids standard by perennial stream.

Table 3.4.2-2. Utah Department of Water Quality evaluations (2018/2020) for watershed units overlapping with CARE (UDWQ 2020b).

Location	Unit ID	Impairments
Fremont River and tributaries from east boundary of CARE to Bicknell	UT14070003-008_00	*E. coli*; Total Dissolved Solids; Temperature
Pleasant Creek and tributaries from east boundary of CARE to headwaters	UT14070003-009_00	Temperature
Oak Creek and tributaries from east boundary of CARE to headwaters	UT14070003-011_00	Temperature
Halls Creek and tributaries from Lake Powell to headwaters	UT14070001-001_00	None

Along the Fremont River and its tributaries (Sulphur, Oak, and Pleasant creeks), water quality samples for *E. coli* have regularly exceeded both chronic (long-term over months) and acute (short-term over hours or days) standards for recreational use (Figure 3.4.2-9; Hackbarth and Weissinger 2018). Exceedances occurred not only during flood events, which typically cause higher turbidity, but also during periods of low flow. High *E. coli* concentrations occurred during the summer months and when livestock were grazed upstream of the park (Hackbarth and Weissinger 2018). Samples were collected on the same day from upper and lower Sulphur Creek during high visitor use between the two sites, but *E. coli* concentrations were not significantly different, suggesting recreational use was not the cause. In addition, the grazing that occurs outside the park may have a higher contribution to the presence of *E. coli* in CARE than the amount of fecal material deposited during limited trailing in the park (NPS, M. Wehtje, biologist, review comment, 2 November 2021 draft).

In contrast to the amount of *E. coli* exceedances, pH levels rarely exceeded reference criteria, with only 13% of samples considered non-compliant in Oak Creek above Sandy Ranch Dam during the 2009 to 2012 sampling period (Hackbarth and Weissinger 2013).

Although channel geomorphology data for the Fremont River are collected by the NCPN, they have not been summarized to include in this report. However, in 2019, the NPS WRD evaluated ten streambank stabilization sites along a ~29-km (13-mi) stretch of the Fremont River in the park for impacts to the fluvial and riparian zones (Martin 2021). No areas of extensive erosion to either the streambank or channel could be attributed to the bank stabilization structures. An overbank flood occurred prior to the 2019 site visit—a regular occurrence that requires “special design considerations” to protect the highway and riparian system from damage (Martin 2021). Further, a 1962 re-route of the stream channel (from an oxbow to a bedrock channel that cut off the oxbow) as part of Highway 24 construction has resulted in bedrock incision and potential threats to the stability of existing infrastructure and riparian resources throughout the corridor (Martin 2021).

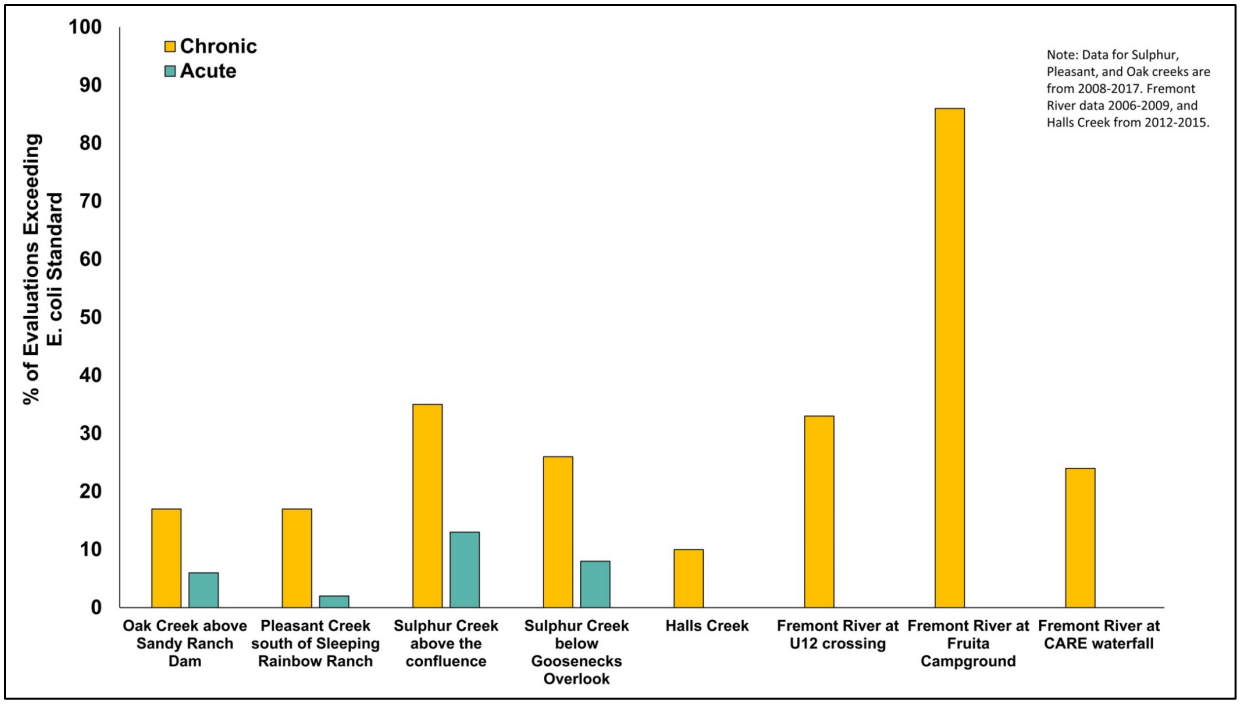


Figure 3.4.2-9. Percentage of water samples exceeding *E. coli* standards by perennial stream.

Geomorphology was also partially addressed by the USFS' Proper Functioning Condition methods (Dickard et al. 2015) at Oak and Pleasant creeks (Martin et al. 2015; Borthwick et al. 2019a,b,c; Borthwick et al. 2020; Borthwick and Livensperger 2017). Of the five geomorphology measures, only one (vertical stability of streambank) met reference criteria in 2019 for Oak Creek (~6.3 km [3.9 mi] from the dam to the western park boundary) because of the "numerous bedrock outcrops and long reaches of bedrock channel" (Borthwick et al. 2020). In contrast, all five measures for both upper and lower Pleasant Creek (1-km [0.6 mi] reaches on either side of the South Draw Road crossing) met reference criteria when last surveyed in 2019 (Borthwick et al. 2019b,c). We are not aware of geomorphology data for other streams in CARE.

A measure related to geomorphology that is of interest to CARE staff is the extent of the riparian zone. For Oak Creek, the channel has significantly widened, reducing the area in which riparian vegetation can establish and grow (Borthwick et al. 2020). However, percentage vegetated ground cover increased from 27% in 2018 to between 55% and 58% in 2019 and 2020 (Borthwick et al. 2020). While this is encouraging, there are many braided sections of Oak Creek that extend to the upland terrace on both sides of the creek. This pattern provides little opportunity for riparian plant growth. At Pleasant Creek, the channel is slightly incised, but not enough that upland plants are invading the riparian zone and narrowing the extent of wetland vegetation (Borthwick et al. 2019b,c).

Auble et al. (2005) estimated that the riparian zone capable of supporting wetland plants along the Fremont River downstream of the gorge was only 2 m (6.6 ft) wide. Highway 24 has also infringed on the riparian corridor of the Fremont River, causing the abandonment of a stretch where the

highway cuts off flow. This change caused channel incision and headcut propagation (NPS 2018a), suggesting the Fremont River, at least along the study reach, is not at its maximum extent.

Historic photos show the Fremont River with a braided channel in what is now the highway corridor within the park; the river is much more channelized today, with road and bank stabilization features, but initial channelization may have been related to climate before highway construction began (NPS, D. Witwicki, NRCA program manager, comments to draft assessment, 18 August 2021). Air photo interpretation of the riparian zone may provide additional information about the extent of the riparian channel. If the imagery is of high resolution, invasive trees and shrubs may be distinguishable from native trees and shrubs, but distinguishing wetland indicator species is key to determining wetland extent.

The NCPN surveys for high-priority invasive plants along the Oak Creek cattle trail, the Pleasant Creek cattle trail, and Highway 24 along the Fremont River (Perkins 2016). Transects are monitored on a 4-year rotating basis. Perkins (2016) summarized these data from 2003 through the 2015 field season. Invasive plant monitoring along Oak Creek revealed high infestation rates of tamarisk in 2015, although the total number of patches declined from 89 in 2003 to 2005 to 48 in 2015. However, some of these patches were larger in 2015 than in 2011. Russian olive increased from one small patch in 2011 to three patches in 2015. Cheatgrass was also mapped along Oak Creek but represented <1% cover along transects surveyed in 2015. Similarly, tamarisk and Russian thistle averaged 0.01% each. During the 2020 Proper Functioning Condition assessment, observers noted that yellow sweetclover (*Melilotus officinalis*), white sweetclover (*M. alba*), and alfalfa (*Medicago sativa*) were common in braided channels that extended from upland terrace to upland terrace, or in places where the channel was incised (Borthwick et al. 2020). Borthwick et al. (2020) estimated that the percentage of non-native herbaceous cover was 5–10% of the total herbaceous cover, with a decrease from the 11–25% estimated in 2019. Two of the target invasive species were documented in at least one year of sampling along Pleasant Creek. These were tamarisk and tree-of-heaven (*Ailanthus altissima*). The latter species occurred in one patch in 2003 but was not detected in subsequent years. The number of tamarisk patches has declined from 100 patches in 2003, 60 in 2010, and 49 in 2014. However, patch size increased over time. Percentage of cover for all three species remained stable from 2010 (5.8%) to 2014 (4.58%) (Perkins 2015).

Russian olive was mapped along Pleasant Creek in earlier surveys, but recent surveys indicate that this species was misidentified. Most, if not all, patches identified as Russian olive were native silverleaf buffaloberry (*Shepherdia argentea*) (NPS, C. Livensperger, plant ecologist, comments to draft assessment, 7 September 2021).

Along Highway 24 and the Fremont River, 71 tree-of-heaven patches were mapped in 2003–2005. In 2013, only two patches were mapped, and none were mapped in 2013. Russian olive and tamarisk were mapped in fewer places in 2013 than during 2009–2010. Not only were there fewer patches, but the percentage of cover declined from 8.42% in 2009–2010 to 5.66% in 2013. However, there were more tamarisk patches within the 400–1,000 m^2 (0.1–0.25 ac) size class in 2013 (78) than in 2009–2010 (21) (Perkins 2016).

In addition to the targeted invasive plant surveys, the NCPN also collects vegetation data along four reaches of the Fremont River. Each reach is sampled on a rotating basis using their wadeable streams monitoring protocol (Weissinger et al. 2018a). We summarized data for the most recent year of sampling for each reach.

The most recent years of sampling were 2018 (Reach 1), 2014 (Reach 14), 2012 (Reach 4), and 2011 (Reach 7) (NPS, R. Weissinger, aquatic ecologist, data file sent to Lisa Baril, Utah State University, 18 February 2021). Note that Reach 7 is an abandoned meander of the main river channel, and the Fremont River no longer flows through it. Although this reach is now considered an upland system, we retained the data summary because it serves as a reference for potential future changes to riparian plants in other reaches as the climate becomes warmer and drier.

Sixteen non-native plant species were encountered across the four Fremont River stream reaches surveyed from 2011 to 2018, four of which are priority invasive species for the NCPN (Perkins 2016). Table 3.4.2-3 shows frequency by species for the most recent year of sampling by reach. The frequency for all non-native plants was highest on Reach 7, primarily because of cheatgrass and Russian thistle. Russian olive was the only NCPN high-priority species not encountered within the four reaches.

The PFC assessments include seven measures of plant diversity, richness, and structure (Dickard et al. 2015). All seven measures for both the upper and lower Pleasant Creek met reference criteria. There was a diverse composition of riparian and wetland species, including willow, cottonwood, wetland grasses, Baltic rush (*Juncus arcticus*), longstyle rush (*Juncus longistylis*), and horsetail (*Equisetum* spp.) (Borthwick 2019b,c). Cottonwood and willow exhibited high vigor, root masses capable of stabilizing streambanks, and a diversity of age classes that indicate recruitment (Borthwick 2019b,c). Overbank cover of trees, shrubs, and herbaceous plants ranged from 88% in the lower reach to 98% in the upper reach, and streambanks were vertically stable. Ground cover averaged more than 50% (78–88%). Although woody debris was rare or largely absent, there were snags located on gravel bars and adjacent to the creek, which could be transported to the creek during high flows. Dead shrubs may also contribute to small, coarse woody debris (Borthwick 2019b,c).

Along the two reaches assessed at Oak Creek in 2020, there was a similar mix of woody trees and shrubs as observed along Pleasant Creek (Borthwick et al. 2020). However, tamarisk was a dominant species, along with cottonwood and willow. Native wetland herbaceous species included common threesquare (*Scirpus pungens*), Baltic rush, longstyle juncus, and horsetail. Although a diversity of plants was present along the creek, the occurrence of many facultative upland species (usually occurs in non-wetlands but sometimes occurs in wetlands), such as copperweed (*Oxytenia acerosa*) and sweetclover, may impede the establishment of riparian vegetation (Borthwick et al. 2020).

Table 3.4.2-3. Frequency of non-native plants by survey reach along the Fremont River.

Species	Common Name	Reach 7 (2011) %	Reach 4 (2012) %	Reach 14 (2014) %	Reach 1 (2018) %
Agrostis stolonifera	Redtop	–	2	16	1
Bromus tectorum [1]	Cheatgrass	79	1	26	–
Chenopodium album	Lambsquarter	1	–	–	–
Chorispora tenella	Blue mustard	16	–	–	–
Elaeagnus angustifolia [1]	Russian olive	–	–	–	–
Elymus repens [1]	Quackgrass	–	–	3	–
Festuca arundinacea	Tall fescue	–	–	–	2
Festuca pratensis	Meadow fescue	–	–	5	–
Halogeton glomeratus	Halogeton	–	2	–	–
Malcolmia africana	African mustard	10	–	–	–
Melilotus alba	White sweetclover	–	1	–	–
Melilotus sp.	Sweetclover	–	5	11	2
Phalaris arundinacea	Reed canary grass	–	–	–	1
Plantago major	Common plantain	–	–	3	2
Ranunculus testiculatus	Bur buttercup	1	–	–	–
Salsola sp.	Russian thistle	86	–	5	–
Salsola tragus	Russian thistle	–	–	–	2
Tamarix spp. [1]	Tamarisk	–	20	13	2

[1] NCPN priority invasive species (Perkins 2016).

Groundcover was estimated at 55% in 2019, and although this is an improvement over the 27% estimated in 2018, a large percentage of streambanks continue to be at risk of erosion. This finding followed the pattern of reduced cattle trailing in June and the elimination of trespass cattle (Borthwick et al. 2020). While willow and cottonwood seedlings were abundant in some places, they need to mature before their root masses are large enough to stabilize streambanks (Borthwick et al. 2020). Overall, the seven PFC vegetation characteristics partially met reference criteria for six measures, while coarse woody debris (7th measure) was absent (Borthwick et al. 2020).

The quality of the riparian plant community along the Fremont River varied by reach. Upland plant richness was highest, and wetland plant richness was lowest, in Reach 7 because this reach is currently considered an upland system (NPS, R. Weissinger, aquatic ecologist, comments to draft evaluation, 16 August 2021) (Figure 3.4.2-10, top). For all four reaches, less than half of all species were obligate (almost always occurs in wetlands) or facultative wetland (usually occurs in wetlands but sometimes in non-wetlands) species. In general, facultative wetland species were more common than obligate wetland species.

The percentage of cover of wetland species ranged from ~11% in Reach 4 to ~24% in Reach 14 (Figure 3.4.2-10, bottom). Wetland plant cover was absent in the monitoring plots along Reach 7.

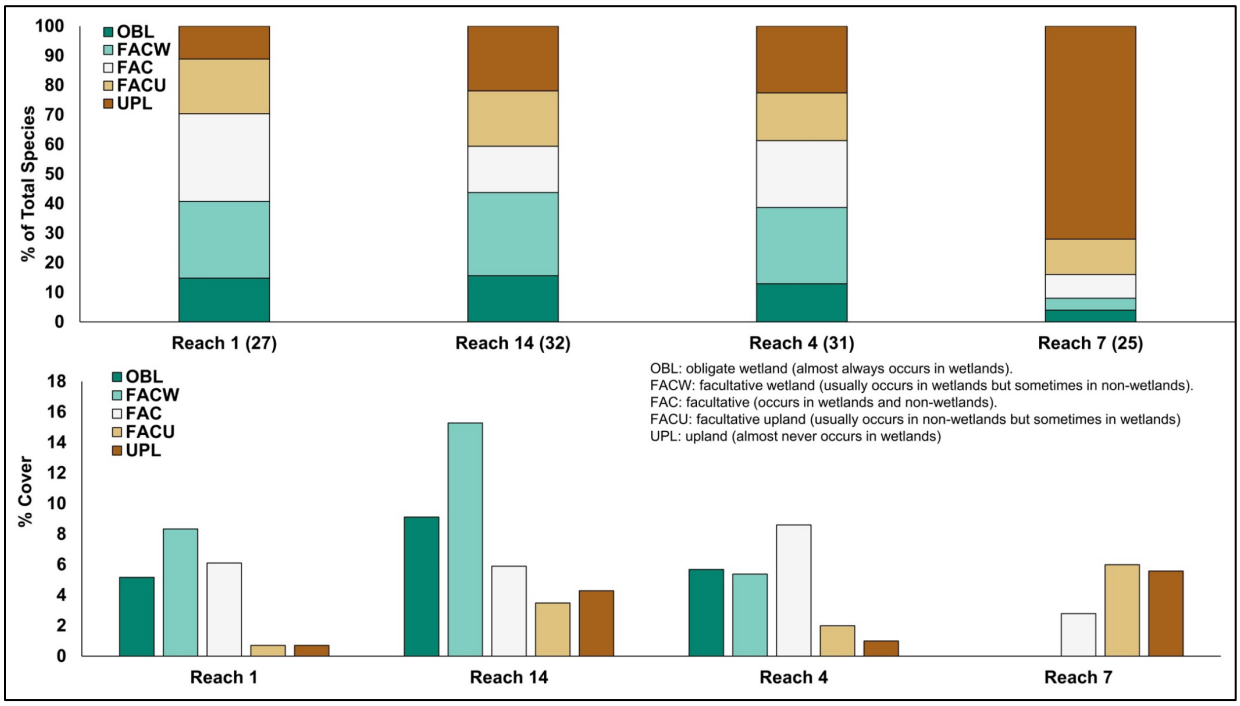


Figure 3.4.2-10. Percentage of plant species (top) and percentage of cover (bottom) by wetland status and stream reach along the Fremont River. Numbers in parentheses indicate species richness.

Shrub cover was the dominant lifeform, except along Reach 7, which was dominated by forbs (Figure 3.4.2-11). Along Reaches 14 and 4, grasses followed shrubs as the dominant lifeform. Of the forbs identified across the four reaches, 11 are upland species, four are facultative upland species,

and one is an obligate wetland species (western goldenrod [*Euthamia occidentalis*]). Of the native graminoids, six are obligate or facultative wetland species and seven are facultative upland or upland species. The obligate wetland species included Nebraska sedge (*Carex nebrascensis*), common spikerush (*Eleocharis palustris*), and common threesquare. The nine native shrub species included two willows (both obligate wetland species) and two facultative wetland species. These were longleaf brickellbush (*Brickellia longifolia*) and spear-leaf rabbitbrush (*Chrysothamnus linifolius*). Fremont cottonwood and Gooding's black willow (*Salix gooddingii*) were the tree species, both facultative wetland species. None of the trees exceeded 50 cm (~20 in) diameter breast height (DBH) (Figure 3.4.2-12). Cottonwoods also exhibited mostly live canopy cover in each reach while Russian olive was mostly dead in reaches 4 and 14.

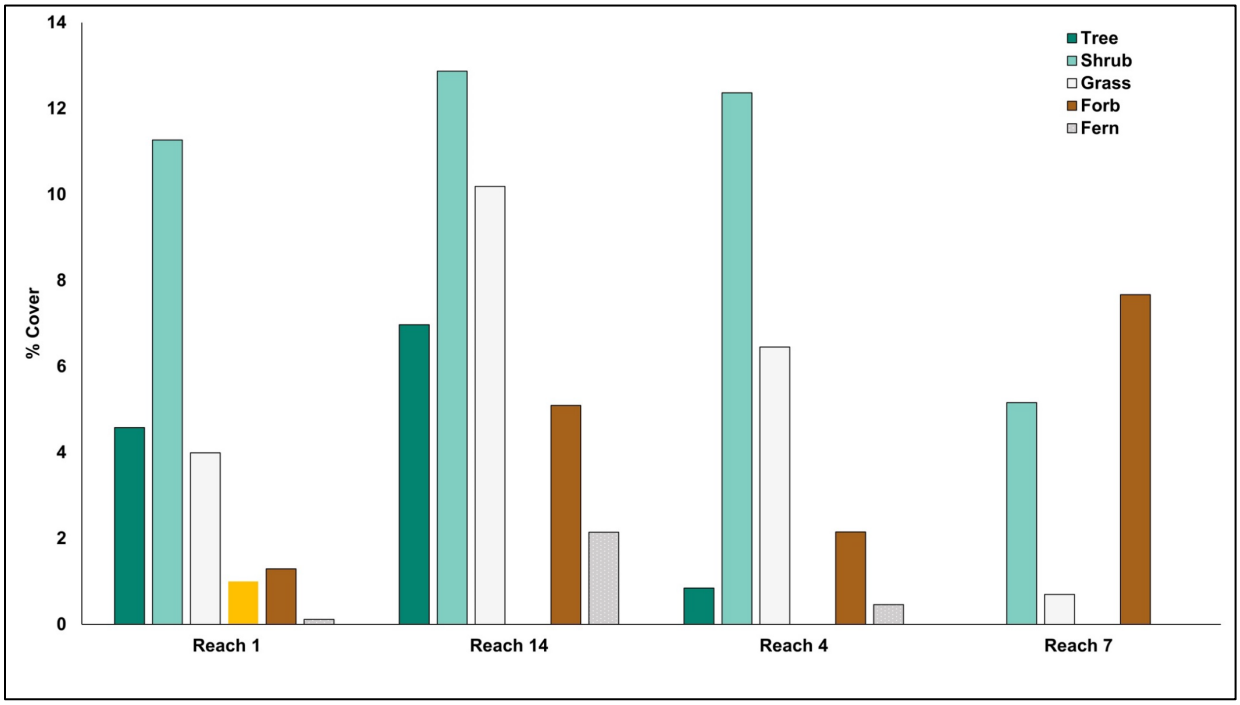


Figure 3.4.2-11. Percentage of cover by lifeform and stream reach along the Fremont River.

According to the NPS ARD, ozone conditions are poor for plant health in the park (NPS ARD 2021b). This was based on the 2014–2018 estimated 3-month W126 metric of 13.7 ppm-hours, which exceeds the benchmark for poor vegetation health ozone condition of 13.0 ppm-hours or greater. Generally, dry conditions in the park during peak ozone concentrations are likely to limit ozone uptake by plants. However, along streams and seeps where conditions are wetter, plants may have higher ozone uptake and injury (Kohut et al. 2012). While plants are at overall low risk of damage from ozone based on the park's environmental conditions (Kohut 2004, 2007), there are ozone-sensitive species in CARE that are riparian obligate or associated species. These are quaking aspen (*Populus tremuloides*) and Goodding's black willow (NPS 2021a). Although quaking aspen is listed as present in CARE (NPSpecies 2021), it has not been observed along the Fremont River and is typically associated with higher elevations.

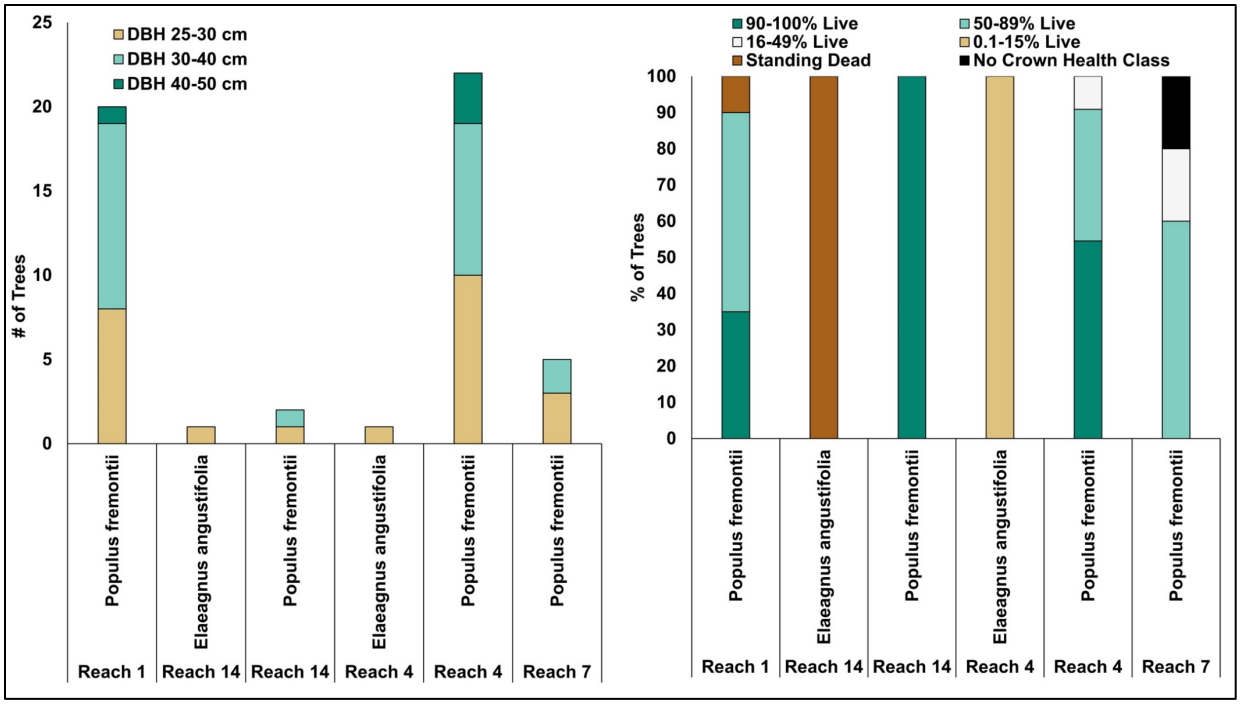


Figure 3.4.2-12. Number of trees by diameter breast height (DBH) and stream reach (left) and percentage of trees by crown health class and stream reach (right).

Other ozone-sensitive plant species that may occur in wetlands are Saskatoon serviceberry (*Amelanchier alnifolia*), common dogbane (*Apocyrum cannabinum*), and western evening primrose. The latter species is considered "probably present" in NPSpecies (2021), but has been confirmed at the park (NPS, C. Livensperger, plant ecologist, comments to draft assessment, 7 September 2021). Over the course of a growing season, ozone can damage plant tissues, making it harder for plants to produce and store food. It also weakens plants, making them less resistant to disease and insect infestations.

Wet sulfur deposition at CARE is low. This is considered good for ecosystem health based on the 5-year average (2014–2018) estimated 0.2 to 0.6 kg/ha/yr range of wet sulfur deposition (NPS ARD 2021b). To maintain the highest level of protection, the maximum of this range (0.6 kg/ha/yr) is used. Ecosystems in the park were rated as having high sensitivity to acidification effects relative to all Inventory & Monitoring parks (Sullivan 20116a,b). Acidification effects can include changes in water and soil chemistry that impact ecosystem health. CARE's plant species sensitive to the effects of acidification include two wetland species: quaking aspen and box elder (*Acer negundo*) (NPS 2021b). If soil acidification does occur, survival for both species may decline, but only box elder is expected to exhibit reduced growth (NPS 2021b).

3.4.3. Discussion

We developed a set of indicators, measures, and reference criteria for a future condition assessment of perennial streams in CARE (Table 3.4.3-1) and discussed them in the previous section for each stream to the extent data were available. The indicators of surface flow, groundwater dynamics, channel geomorphology, and vegetation structure and composition are from the NCPN's wadeable

streams protocol (Weissinger et al. 2018a). The one exception is the measure of change in cover and extent (vegetation structure and composition indicator), added per CARE's request, which could be evaluated using fine-scale aerial imagery. For the measures of surface flow and groundwater dynamics, reference criteria were derived from Lukas and Payton (2020) and Stromberg et al. (1996), respectively. Reference criteria for geomorphology and vegetation composition and structure were adapted from Dickard et al. (2015) PFC functional condition statements. Water quality measures were based on the NCPN vital signs as described in Thoma et al. (2017), with associated reference criteria obtained from UDWQ standards (UDWQ 2020a,b). Vegetation health measures and reference criteria were derived from NPS ARD's protocol (Taylor 2020).

Table 3.4.3-1. Proposed study details for riparian.

Indicator of Condition	Measure	Reference Criteria for Measure
Surface Flow	Flow variability (magnitude, timing, duration)	Flow variability mimics historic patterns, particularly during spring.
Groundwater Dynamics	Depth to alluvial groundwater	≤2.0 m for woody seedling establishment; <4 m for maintenance of woody mature species.
Water Quality	Core parameters (nitrogen, phosphorus, pH, total dissolved solids, *E. coli*)	Fewer than 10% of samples exceed the criteria for supported uses (must meet minimum sample size of 10/site).
Channel Geomorphology	Floodplain width and elevation	The accumulation of geomorphological characteristics indicates that the stream channel is in "dynamic equilibrium." There are no values or specific reference criteria for the individual measures.
	Channel width and depth	The accumulation of geomorphological characteristics indicates that the stream channel is in "dynamic equilibrium." There are no values or specific reference criteria for the individual measures.
	Channel planform	The accumulation of geomorphological characteristics indicates that the stream channel is in "dynamic equilibrium." There are no values or specific reference criteria for the individual measures.
	Channel slope	The accumulation of geomorphological characteristics indicates that the stream channel is in "dynamic equilibrium." There are no values or specific reference criteria for the individual measures.
	Composition of bed material	The accumulation of geomorphological characteristics indicates that the stream channel is in "dynamic equilibrium." There are no values or specific reference criteria for the individual measures.
Vegetation Structure and Composition	Change in cover and extent of riparian zone	No declines in riparian cover and extent. Riparian is expanding or has achieved its potential extent.

Table 3.4.3-1 (continued). Proposed study details for riparian.

Indicator of Condition	Measure	Reference Criteria for Measure
Vegetation Structure and Composition (continued)	Non-native plants presence/absence or frequency of invasive species	Non-native plants may be present, but species that have the greatest negative impact on ecosystem structure and function are absent or very limited.
	Richness	There is diverse composition of riparian wetland vegetation for maintenance and recovery. Species present indicate maintenance of riparian soil-moisture characteristics.
	Cover by lifeform and wetland status	Adequate riparian wetland vegetative cover is present to protect banks and dissipate energy during high flows. Riparian plants exhibit high vigor (mostly live vegetation).
	Basal area and density of woody species	There are adequate age classes of stabilizing riparian vegetation for recovery and maintenance.
	Canopy closure	Trees exhibit high vigor (mostly live vegetation).
Vegetation Health	Ozone	<7 ppm-hrs
	Sulfur	<1 kg/ha/yr

There are current NCPN data for all indicators for the Fremont River. Additionally, the PFC assessments conducted by CARE staff for Pleasant and Oak creeks provide current data for assessing the condition of vegetation structure and composition and channel geomorphology, though these rapid assessments are less detailed than NCPN's methods. During the 2015 assessment, Oak Creek was "non-functional" due to the "poor condition of riparian wetland vegetation and a degraded channel/floodplain form along much of the creek" (Martin et al. 2015). Reassessments in 2017, 2019, and 2020 found the stream still in "non-functional" condition; however, plant cover had increased, and soil disturbance was reduced compared to 2015 (Borthwick and Livensperger 2017; Borthwick et al. 2019a; Borthwick et al. 2020). In contrast, assessments of Pleasant Creek in 2015 and 2019 found the riparian zone to be in "proper functioning condition" (Martin et al. 2015; Borthwick et al. 2019b,c). Water quality data are also current for the Fremont River, and Pleasant, Sulphur, Halls, and Oak creeks. Although a subset of non-native plant species was mapped along Sulphur Creek, these are the only data on vegetation structure and composition available for this stream.

Table 3.4.3-2 shows the gaps in riparian monitoring by stream. The NCPN surveys the Fremont River along four eastern reaches, totaling 14.9 km (9.3 mi) in length (Weissinger et al. 2018a). The remaining 34 km (21.1 mi) of the Fremont River within CARE are not surveyed because one stretch is highly managed and the other occurs within a constricted canyon setting (Weissinger et al. 2018a).

Table 3.4.3-2. Summary of current (i.e., <10 years old) data available by stream in CARE.

Stream	Discharge	Alluvial Groundwater	Water Quality	Channel Geomorphology	Vegetation Structure and Composition
Fremont River	Four sites (reaches) along 14.9 km (9.3 mi) of stream from eastern park boundary west.	Four sites (reaches) along 14.9 km (9.3 mi) of stream from eastern park boundary west.	One site before the river enters CARE.	–	14.9 km (9.3 mi) reach from eastern park boundary west, but non-native plant surveys occur from just below confluence with Sulphur Creek to east entrance.
Sulphur Creek	Two NCPN water quality sites from 2008–2020.	–	Two NCPN water quality sites from 2008–2020.	–	–
Pleasant Creek	One NCPN water quality site from 2008–2020.	–	One NCPN water quality site from 2008–2020.	PFC assessments along 2 km (1.2 mi) downstream and upstream of South Draw Road crossing.	PFC assessments along 2 km (1.2 mi) downstream and upstream of South Draw Road crossing, but NCPN surveys non-native plants along entire length.
Oak Creek	One NCPN water quality site from 2010–2020.	–	One NCPN water quality site from 2010–2020.	PFC assessments along 6.3 km (3.9 mi) from Oak Creek Dam to west park boundary.	NCPN and PFC assessments along 6.3 km (3.9 mi) from Oak Creek Dam to west park boundary, but NCPN surveys non-native plants along entire length.
Polk Creek	–	–	–	–	–
Halls Creek	One NCPN water quality site from 2006–2020.	–	One NCPN water quality site from 2006–2020.	–	–

The PFC assessments evaluate 6.3 km (3.9 mi) of the 9.7 km (6 mi) of Oak Creek that flow through the park. The PFC also evaluates 2 km (1.2 mi) of Pleasant Creek on two separate 1-km (0.6-mi) reaches on either side of the South Draw Road crossing. The upper reach is located 2.1 km (1.3 mi) from the road crossing, extending upstream. The lower reach begins 1.2 km (0.75 mi) downstream of the road crossing and extends downstream. A total of 11.3 km (7 mi) of Pleasant Creek flow through the park (Martin et al. 2015).

There are multiple water quality impacts from upstream land uses (e.g., water withdrawals and agriculture), airborne mercury deposition, and livestock trailing and grazing along Oak and Pleasant creeks within the park (NPS 2018a). Stream pollution of the Fremont River comes from "nonpoint-source runoff from animal husbandry, agricultural lands, and human effluent waste" (NPS 2018a). As visitor use increases, especially in Spring Canyon, Halls Creek Narrows, and Pleasant Creek, water quality issues are likely to persist.

Cattle trailing and visitor use of riparian habitat can serve as sources of invasive plants. The persistent disturbance of trailing also reduces the ability of riparian vegetation to recover, allowing invasive species to expand. In riparian areas, cattle grazing and trailing are more concentrated and damaging to plants than in other areas, because grazers are more concentrated in the narrow zone of a riparian corridor (NPS 2018b). Consequences of grazing and trailing observed in CARE include compaction of soils, reduced water infiltration, bank destabilization, reduced abundance of native plants, and the introduction of non-native and invasive species.

Climate change, including the shifting of precipitation intensity and timing, could alter patterns of flooding and seasonal runoff, change soil moisture, and cause extended periods of extreme drought (NPS 2018a). In a study evaluating the effects of flow alteration on wetland and riparian plants along the Fremont River in CARE, Auble et al. (2005) found that wetland plants typically occur on sites inundated for at least two weeks per year. Riparian along the high-gradient study reach capable of supporting wetland species was narrow (2 m [6.6 ft] wide). By "using individual plant species distributions on an inundation duration gradient, coupled with a hydraulic model," Auble et al. (2005) estimated the magnitude and direction of vegetation change in response to flow alteration. But determining the rates of change was more complex. Variability in flow was an important determinant of wetland plant responses, with greater variability associated with a wider wetland plant zone. The effect of flow variability on the width of the wetland zone also depended on discharge magnitude or flooding, with higher magnitude flows associated with wider wetland zones (Auble et al. 2005).

But maintenance of healthy riparian plant and wildlife communities (e.g., fish, macroinvertebrates, birds) depends on preserving the in-stream water supply in CARE's perennial streams. CARE maintains state appropriative water rights and federal reserved water rights (NPS 2018a). While the federal water rights have not been quantified, state water rights require the use of the allocation or the park risks losing these rights (NPS 2018a). In addition to upstream withdrawals of the Fremont River, there are upstream water withdrawals on Oak and Sulphur creeks and multiple groundwater withdrawals surrounding the park (NPS 2018a). While only two groundwater supply wells exist in CARE, the Utah Division of Water Rights records show that hundreds of groundwater supply wells exist near the surrounding Utah towns of Torrey, Teasdale, Grover, Bicknell, Boulder, Notom,

Caineville, and Ticaboo. Understanding how the current amounts of groundwater pumping and available groundwater storage compare requires future hydrogeologic studies to address this knowledge gap (NPS, T. Gilkerson, hydrogeologist, draft introduction to CARE hydrogeology and groundwater resources, 4 June 2021).

3.5. Pinyon-Juniper Woodlands (Condition Assessment)

3.5.1. Background & Importance

Woodlands characterized by two-needle pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) comprise a significant portion of CARE, forming the dominant vegetation class over 57% of the park at low to mid-elevations. Pinyon and juniper cover and density have been expanding throughout the interior West via processes of infill (densification), as well as expansion into other vegetation types (Miller et al. 2008, 2019). An accelerated rate of infill in the late 1800s and early 1900s was driven largely by climate (Miller et al. 2019), as a relatively cool period increased seed production (Redmond et al. 2012), seedling establishment (Chambers 2000), and mortality (Breshears et al. 2005). Romme et al. (2009) note that "Although recent woodland expansion has received much attention ..., contraction of woodlands has also been documented." They argue that over the centuries and millennia there have been fluctuations in areal extent of pinyon-juniper woodlands, largely in response to climatic conditions. The comparatively cooler and wetter period in the late 19th and early 20th centuries is one such influence. Romme et al. also found that on the Colorado Plateau conditions vary locally, e.g., minimal change in total coverage on the Uncompaghre Plateau but infill in northern Arizona and extensive infill and expansion further south in Arizona and New Mexico. In the absence of information specific to CARE and its surrounding area, a reference to regional-level expansion seems most appropriate. The Miller et al. (2019) review is the most recent such reference, and two of its authors also authored the Romme et al. (2009) paper.

The more recent infill and expansion across the Colorado Plateau include a combination of influences, including livestock grazing that reduces competition from more palatable species, changing fire regimes, and climate change (Baker 2011; Miller et al. 2011, 2019). Both species tend to be small, slow-growing, and relatively long-lived (>200 years for *P. edulis* and ≥ 650 for *J. osteosperma*) (Tausch et al. 1981). Utah juniper is less susceptible to drought than pinyon pine (Hartsell et al. 2020); however, there are reports that *J. osteosperma* also is suffering drought impacts (Stapleton 2019; Kannenberg et al. 2021) as the southwest U.S. experiences a multi-decadal drought (Williams et al. 2020).



Pinyon pines have been used by humans for thousands of years for food and shelter. Image Credits: NPS / EMILY VAN NESS.

Although they superficially appear homogeneous and low in productivity, pinyon-juniper woodlands can vary greatly in age, structure, and composition (Romme et al. 2009). This broad heterogeneity creates a variety of habitats that are important for vertebrate and invertebrate species. For example, of seven forest habitats common in eastern Utah, pinyon-juniper communities rank second in the percentage of obligate and semi-obligate bird species, third in the number of individual birds counted, and fourth in bird species richness and diversity (Paulin et al. 2001). However, infill can reduce this heterogeneity with potential detrimental effects on wildlife. For example, pinyon jay (*Gymnorhinus cyanocephalus*) populations are thought to be in steep decline, partly due to reductions in pinyon pinecone crops, but also due to changes in woodland stand structure occurring as a result of drought and woodland densification (Boone et al. 2018).

3.5.2. Study Framework

We used four indicators and seven measures to assess the condition of pinyon-juniper woodlands at CARE (Table 3.5.2-1). Three of the indicators address conditions and trend of woodland density, while the fourth considers habitat quality by assessing trends in counts for pinyon-juniper-dependent bird species. Monitoring of pinyon-juniper woodlands at CARE is conducted by the USFS Inventory and Analysis (FIA) program at 17 repeat-sampled plots (USFS, J. Shaw, research forester, provided data on 19 January 2021 to M. Brunson). Additional vegetation information is available for two bird transects monitored by the NCPN. Vegetation maps were produced for the park by Coles et al. (2009), but more recent information is available from the National Agricultural Imagery Program (NAIP). NAIP imagery collected in July 2018 was used to assess juniper canopy cover. Count data for two pinyon-juniper bird species, pinyon jay and ash-throated flycatcher (*Myiarchus cinerascens*), are from observations made in 2005–2019 along two USGS Breeding Bird Survey (BBS) transects; we compared these data with NCPN analyses reported by Roberts et al. (2020). (See songbirds condition assessment for details on data collection.).

Table 3.5.2-1. Study details for the pinyon-juniper woodlands condition assessment.

Indicator of Condition	Measure	Reference Criteria for Measure
Tree Density	Stand density index	SDI <200, based on FIA data for at least 90% of plots
	Crown cover (%)	<25% for at least 90% of FIA plots
Crown Cover Increase	Plot-level change in stand density in repeat-measured plots	Change in SDI ≤ ±2% over ~10 years
	Plot-level change in crown cover in repeat-measured plots	Change in crown cover ≤ ±2% over ~10 years
Obligate Songbirds	Pinyon jay	Stable or upward trend in observations
	Ash-throated flycatcher	Stable or upward trend in observations
Age Class Distribution	Relative proportion of low-, medium-, and high-density juniper stands	≥60% in early development stage (0–25% canopy cover); ≥30% in mid-development stage (25%–35% canopy cover); ≤10% in late development stage (>35% canopy cover)

Reference criteria are based on studies showing that as woodland density increases, understory vegetation cover and species richness decreases (Huffman et al. 2017; Roundy et al. 2014). Accordingly, we assumed that to support a wider variety of understory plant species and the animal communities dependent on those species, an open woodland condition would be more desirable than a closed canopy. Selection of specific numeric reference criteria were based first on guidance from the USFS FIA program regarding the threshold at which forest thinning should occur in pinyon-juniper communities, using a measure called stand density index (SDI), which is based on the number of trees per unit area and average tree size within a stand. Page (2008) has suggested that when canopy cover has reached 35% in uneven-aged pinyon-juniper stands, foresters should consider thinning to avoid loss of understory vegetation and associated ecosystem services. In the FIA plots within CARE, 35% crown cover translates to an SDI of ~250. However, since the expansion process is continuing regionwide, a more conservative threshold of 25% crown cover and SDI < 200 was selected. As of 2019, FIA had remeasured 17 plots that could be used to assess change in canopy cover over a 10-year period.

The relationship between woodland density and pinyon-juniper bird species is non-linear: Some species depend on shrubs within an open pinyon-juniper woodland matrix, while others require mature trees as breeding habitat. In an expanding woodland, open woodland/shrub habitat may decline for several decades before breeding habitat is available for species dependent on mature trees (Fleishman and Dobkin 2009). Both of our two indicator bird species, pinyon jay and ash-throated flycatcher, depend on pinyon-juniper woodlands for foraging and nesting habitat but require distinct and different subsets of habitat. Boone et al. (2021) found that jays use areas with low tree cover for seed caching, variable tree cover for foraging, and high tree cover for nesting. Ash-throated flycatchers are cavity-nesters requiring older trees than pinyon jays, which are tree-nesters (Rosenstock and van Riper III 2001). Therefore, we assumed that stable or increasing trends of both species would indicate that a suitable range of open and mature woodland are available.

To assess diversity in woodland density conditions, we measured the relative proportion of low-, medium-, and high-density stands within the park. LANDFIRE (2019) has developed a vegetation dynamics model for pinyon-juniper woodlands that identifies condition classes based on the percentage of tree cover. The early development phase is characterized by 0–30% tree cover with grasses, forbs, shrubs, and tree seedlings present. An open stand is described as 10–40% tree cover and a closed stand is 40%–70% cover. Both closed and open stands have mid- and late-development stages that differ in terms of the age and size of mature trees within the matrix. Based on Page's suggestion of 35% as a threshold to consider thinning, we categorized woodland density in three stages: an open condition with less than 25% canopy cover, a mid-level condition of 25–35% cover, and a closed condition where cover exceeds 35%. On the assumption that the regionwide trend toward increasing woodland density would apply to CARE as well, we chose a reference condition that favored open, and early-development stands over closed and later-development stands that may be more susceptible to catastrophic wildfire.

However, this assumption may not account for effects of a "megadrought" (i.e., an extended period of drier-than-normal weather lasting 20 years or more), such as climate scientists believe is occurring

currently in the U.S. Southwest (Szejner et al. 2020; Williams et al. 2020). The Medieval Warm Period (C.E. 900–1300) included the four driest periods in the past 1,300 years (Cook et al. 2004), leading to a significant decline in the total area occupied by pinyon and juniper (Miller and Wigand 1994). A megadrought would almost certainly increase pinyon and juniper mortality, although the regional pattern of future mortality (e.g., patchy vs. widespread) remains unknown. Severe drought in 2002–2004 resulted in significant pinyon-juniper mortality regionwide; an Arizona study found that drought-induced mortality reduced the canopy by 55%, offsetting any cover increases that had been measured since 1936 (Clifford et al. 2011). While drought was the ultimate cause of tree mortality, proximate causes included combined effects of infestation by ips beetle and pitch moth, root disease, and mistletoe parasitism (Shaw et al. 2005). However, if drought becomes severe enough, lack of water alone can cause significant mortality, as appears to have been the case for a rapid dieback of Utah juniper in the Southwest in 2018 (Kannenberg et al. 2021). When drought reduces the pinyon-juniper tree canopy, understory vegetation may increase. A recent analysis in Nevada found understory cover increased only in drier sites, with greater growth response by cheatgrass than native perennials (Flake and Weisberg 2021). Because rainfall patterns differ between the Great Basin and Colorado Plateau, it is not known whether a similar dieback at CARE would lead to an increase in cheatgrass cover.

CARE managers have asked if there is a soil moisture limit below which pinyon-juniper communities are likely to decline. The answer is likely to depend on tree species, and on the timing of precipitation during an extended drought. Failure of a summer monsoon is likely to affect two-needle pinyon pine more than Utah juniper, as pinyon pines respond to, and may depend upon, annual monsoon-driven increases in summer water availability, while junipers do not (West et al. 2007). However, Urza et al. (2020) have identified a topoclimatic limitation for the lower treeline of pinyon-juniper woodlands in the Intermountain West–that is, at some point it gets too hot and dry for junipers as well. Higher temperatures and associated droughts are likely to shift the treeline upward. Estimates of evapotranspiration rates for pinyon-juniper woodlands range as low as 0.2 mm day^{-1} (Lane and Barnes 1987; Miller et al. 1987). During the heat of summer, almost all of that water is drawn from deeper soil layers (Leffler et al. 2002), making it difficult to monitor whether a soil-moisture limit has been reached.

3.5.3. Data & Methods

To assess tree density and cover increase at the plot scale, we used data supplied by the USFS FIA program (USFS, J. Shaw, research forester, provided data on 19 January 2021 to M. Brunson), which inventories a sample of all forested lands in the U.S., regardless of ownership or availability for forest harvesting. Plots are located according to a uniform grid, applied nationwide. Each plot consists of four circular, 7.32-m (24.0-ft) radius subplots arranged in a fixed pattern (USFS 2017). Plots may straddle multiple vegetation classes, including forest as well as non-forest types. For this analysis, FIA scientists supplied a data set of plots with coordinates that fall within CARE and have *P. edulis* and/or *J. osteosperma* as dominant species. Seventeen of the plots had been sampled twice, 10 years apart, providing a simple measure of mean change in density and cover. In addition, seven plots that had been characterized as "non-forest" and thus not sampled in the decade 2000–2009 were re-classified as "forest" in the subsequent sampling cycle, indicating that tree density had increased

sufficiently to warrant a change in status. For woodland types, the criteria used for classification as non-forest is less than 5% stocked (USFS 2017). Stand density index and crown cover percentage were reported for each of the 24 plots included in the analysis.

In addition, woodland cover was assessed parkwide via remote sensing. For this analysis, a rapid assessment was conducted focusing on juniper cover only, as this species is most numerous within the park and pinyon pine is nearly always found intermixed with juniper. To map juniper canopy cover we used high, 1-m (3.3 ft) resolution NAIP imagery collected July 23–Sept. 6, 2018 (NAIP 2018). These data included standard red, green, and blue layers to depict a natural color image, as well as a near-infrared layer to identify actively growing vegetation. Initial image processing used Google Earth Engine to generate a simple tree/non-tree canopy classification. This product was imported into ArcGIS Pro, where final mapping was performed. A simple conversion of NAIP imagery into a normalized difference vegetation index (NDVI) was completed, using the available near infrared and red bands. The NDVI values were thresholded to separate green vegetation from the surrounding non-green background. Because the images were captured in late summer, there was clear differentiation of trees, irrigated areas, and riparian vegetation from natural herbaceous dryland vegetation. Actively growing non-tree vegetation was eliminated by masking the thresholded NDVI layer with a Utah Division of Water Resources GIS layer (Utah Geospatial Resource Center 2021). Riparian vegetation was eliminated using the higher resolution National Hydrography Database (USGS 2020a); primary rivers were buffered by 20 m (66 ft) and all other rivers by 10 m (33 ft), and these buffers were used to mask out green areas at those locations. To estimate canopy cover, the thresholded NDVI layer was converted to a binary grid (1=juniper present, 0=absent). A circular focal (or convolution) filter of three different radii was used to count the number of juniper pixels within each focal area. Since juniper was coded to 1, a simple sum of pixel values within each focal area provided a count of pixels corresponding to juniper. Dividing the juniper pixel count with the total number of possible pixels in each focal area yielded the percentage of canopy cover. Canopy cover was estimated using three sizes of circular focal filters corresponding to 0.1 ha (0.25 ac) (18 m/59 ft radius), 0.5 ha (1.2 ac) (40 m/131 ft radius), and 1.0 ha (2.5 ac) (57 m/187 ft radius). Juniper canopy cover was categorized into three cover classes of 1–25%, 25–35%, and > 35%.

To assess population trends for our two woodland-dependent songbird indicator species, ash-throated flycatcher and pinyon jay, we used data from the NCPN, as reported by Roberts et al. (2020). NCPN maintains two transects within CARE's pinyon-juniper woodland as part of a larger study that surveys birds in 12 of the 16 national parks covered by the network. Results from two transects are not sufficient to monitor trends in the populations at the park level; however, as a proxy we report network-wide trends reported by Roberts et al. (2020). For further details on songbird analysis, see section 3.8 of this report.

3.5.4. Results & Discussion

For the 24 FIA plots classified as forest in 2010–2019, values for stand density index (SDI) ranged from 32 to 256. Two plots (8.3%) exceeded the reference criterion of SDI=200. The frequency distribution of SDI values is shown in Figure 3.5.4-1.

Three plots (12.5%) exceeded the 25% cover threshold (Figure 3.5.4-1) and one, which also had the highest value for SDI, reached "maximum occupancy" as defined by Page (2008). Therefore, for the tree density indicator, as measured at the plot scale, there is little indication that pinyon-juniper woodlands are reaching a closed-canopy condition that is likely to lead to increased risk of wildfire or loss of ecosystem services. While a few plots are at or near a threshold where the site might be considered "fully occupied" (Page 2008), the vast majority of FIA plots are well below the threshold and unlikely to reach it for several decades.

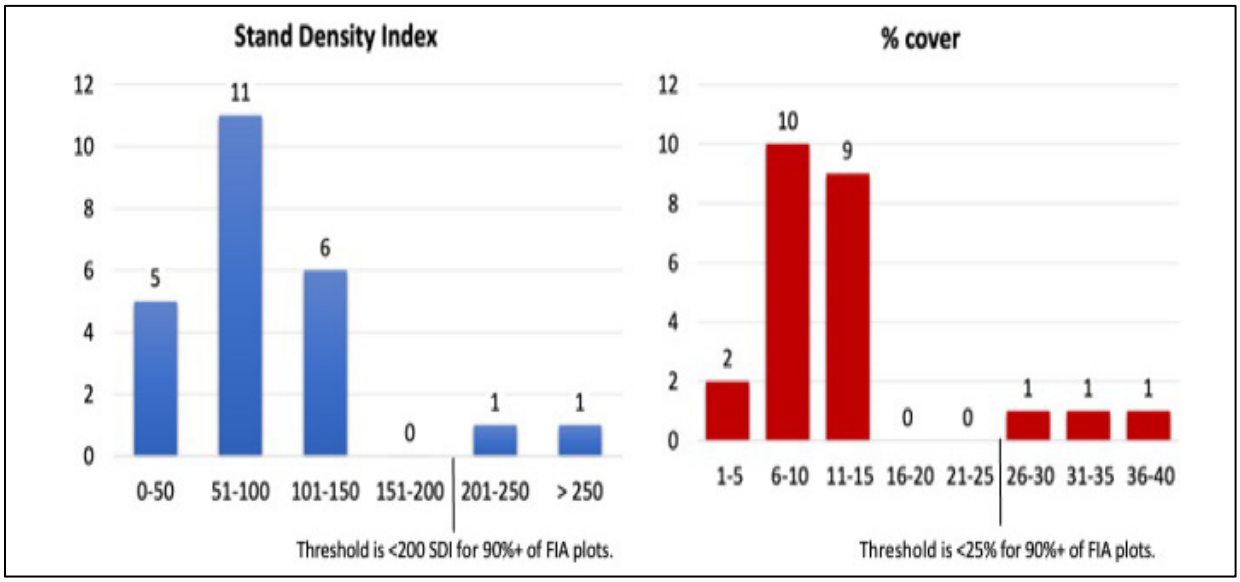


Figure 3.5.4-1. Frequency distribution of stand density index and % crown cover of pinyon-juniper plots measured by USFS Forest Inventory and Analysis crews, 2010–2019.

Because FIA plots are measured on a decadal cycle, and sampling has occurred since 2001, we were able to assess densification trend (infill) by comparing SDI measurements between decades. Of the 17 plots that have been repeat-measured, values for SDI had increased in 9 plots between 2001–2010 and 2011–2019. However, values for SDI had actually decreased in the other 8 plots. Mean change in SDI was −1.01, or a 1.6% decrease in mean SDI over the 17 plots. The greatest increase in SDI occurred in the densest plot, where the value increased from 237.8 to 255.9 ($\Delta = 18.1$) between 2001 and 2011. The greatest decrease was from 101.0 to 66.2, or approximately one-third ($\Delta = 34.8$), between 2008 and 2018. This pattern of increasing density at some plots and decreasing density at others is likely to reflect localized responses to the region's frequent droughts. Statewide, Utah experienced a drought period of 288 weeks in the first half of the 2000s, with the most severe conditions in 2002–2004 when the most intense impact was in the southern half of the state. Another milder drought occurred in 2012–2015, a short but severe drought occurred in 2018, and another severe drought began in June 2020 and continued through 2021 and likely beyond (NIDIS 2021). As noted previously, drought effects on pinyon-juniper woodland can be severe, setting back the successional clock by decades (Clifford et al. 2011).

Change in crown cover followed a similar pattern to tree density. The FIA surveys found an increase in crown cover in 7 plots, a decrease in 9 plots, and no change in 1 plot. The largest increase was 14% in the densest plot, while the largest decrease was 7%. Mean change in crown cover was 0.7%, or 5.7% of the average crown cover of 12.4%. However, the entire change can be accounted for by densification in one plot.

As noted previously, seven FIA plots that were characterized as "non-forest" in 2000–2009 had been re-classified as "forest" in the subsequent decadal sampling cycle, suggesting that tree density had increased. Canopy cover in those plots ranged from 6% to 11% during the most recent sampling period. These changes indicate that a process of woodland expansion is occurring in the park, although without high-resolution historical records we were unable to determine whether this increase represents transition from grass-shrub condition to woodland or re-occupation of woodland lost to a previous disturbance.

Because not all pinyon-juniper bird species require the same habitat characteristics, we can assume woodland condition is good if population trends are stable or increasing for species with differing habitat needs. NCPN analyses of network-wide population trends for ash-throated flycatcher and pinyon jay are stable (see section 3.8 for details, Table 3.8.4-4). The stable population trend for pinyon jay, a species whose populations are in decline range-wide (Boone et al. 2018), indicates that the condition of pinyon-juniper woodlands in the region's NCPN parks remain sufficiently heterogeneous that the species can obtain its diverse habitat needs. Within CARE, Roberts et al. (2020) reported twice as many detections of pinyon jay as of ash-throated flycatcher in the two NCPN pinyon-juniper transects; however, detections of these species fluctuate considerably from year to year (Figure 3.5.4-2).

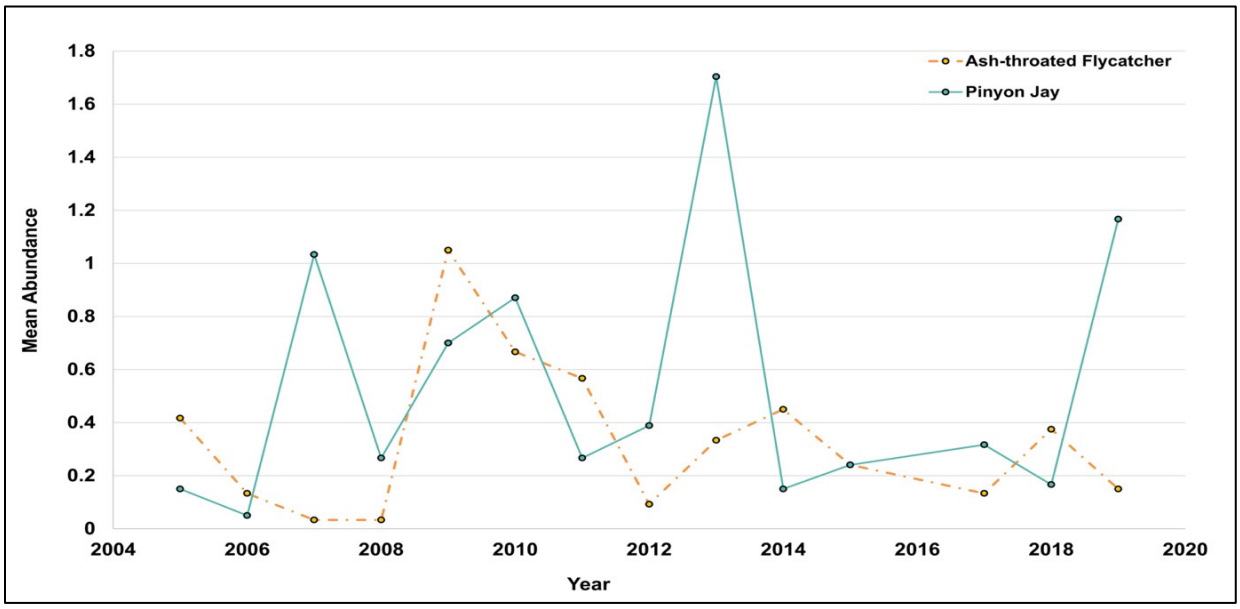


Figure 3.5.4-2. Annual mean number of detections of pinyon jay and ash-throated flycatcher, 2005–2019.

For age-class distribution, we used remote sensing imagery to assess juniper cover parkwide. This analysis focused on Utah juniper, which is the more numerous of the woodland species. Juniper canopy cover was categorized into three cover classes of 1–25%, 25–35%, and > 35%. Canopy cover was estimated using three sizes of circular focal filters corresponding to 0.1 ha (0.25 ac) (18 m/59 ft radius), 0.5 ha (1.2 ac) (40 m/131 ft radius), and 1.0 ha (2.5 ac) (57 m/187 ft radius). Estimates of canopy cover differed depending on the filter used:

- 0.10 ha (0.25 ac) radius focal filter: 384 of 1,009 pixels counted as juniper (38% cover)
- 0.50 ha (1.2 ac) radius focal filter: 1,484 of 5,025 pixels counted as juniper (30% cover)
- 1 ha (2.5 ac) radius focal filter: 3,294 of 10,189 pixels counted as juniper (32% cover)

The three focal filter sizes provided a comparison of the effect of plot size on the percent canopy estimate. The 0.1 ha (0.25 ac) filter may be overly sensitive to local variations, while the 0.5 (1.2-ac) and 1.0-ha (2.5-ac) plots were less sensitive to local variation and provide comparable results (Table 3.5.4-1).

Table 3.5.4-1. Percentage of estimated juniper occurrence within three cover classes, using three different-sized plots.

Cover Class	0.1 ha radius filter (% of park)	0.5 ha radius filter (% of park)	1.0 ha radius filter (% of park)
0–25%	49.2	55.3	57.4
25–35%	4.1	3.8	3.8
>35%	3.4	2.9	2.7
No juniper	43.3	38.0	36.1

Juniper is distributed throughout the park (Figure 3.5.4-3), with 20% or less canopy cover across most areas. The densest woodlands are located along the park's western border in the far northern and central regions, adjacent to or within 1 km (0.62 mi) of multiple-use federal lands (Figure 3.5.4-4). These lands are likely to be at most risk of catastrophic wildfire, because of their density and the possibility of spread from adjacent jurisdictions. However, they represent less than 3% of the entire park area. The reference criteria for cover-class distribution were chosen to favor low-density woodlands in an early stage of development. Depending on focal filter size, the 0%–25% cover class represents between 86.8% and 89.8% of the total juniper landscape within the park, while the mid-development stage (25%–35%) represents 5.9%–7.2% of the juniper within the park, and the late-development stage (>35%) represents 4.2%–6.0% of the juniper stands in the park.

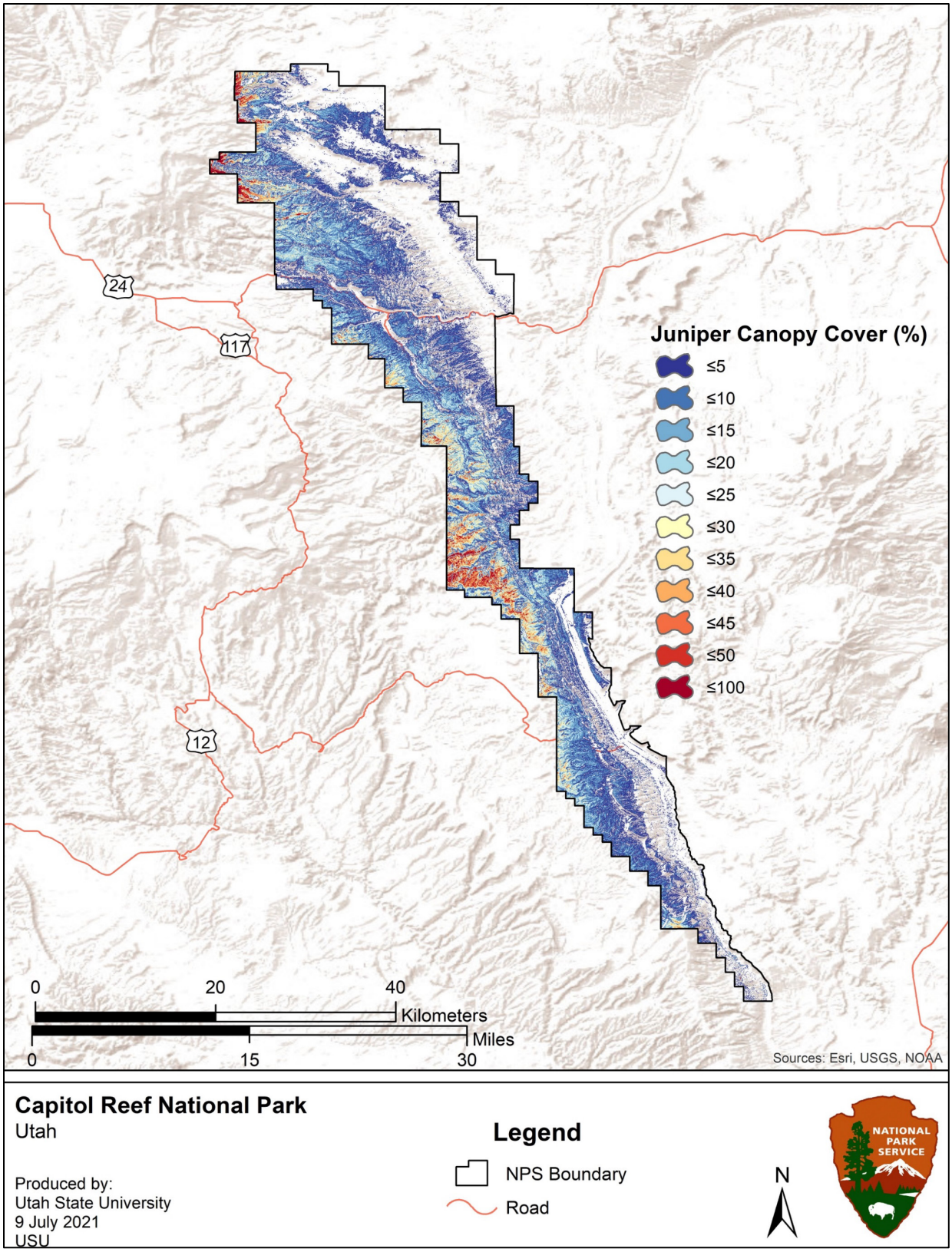


Figure 3.5.4-3. Spatial distribution of juniper cover classes across CARE.

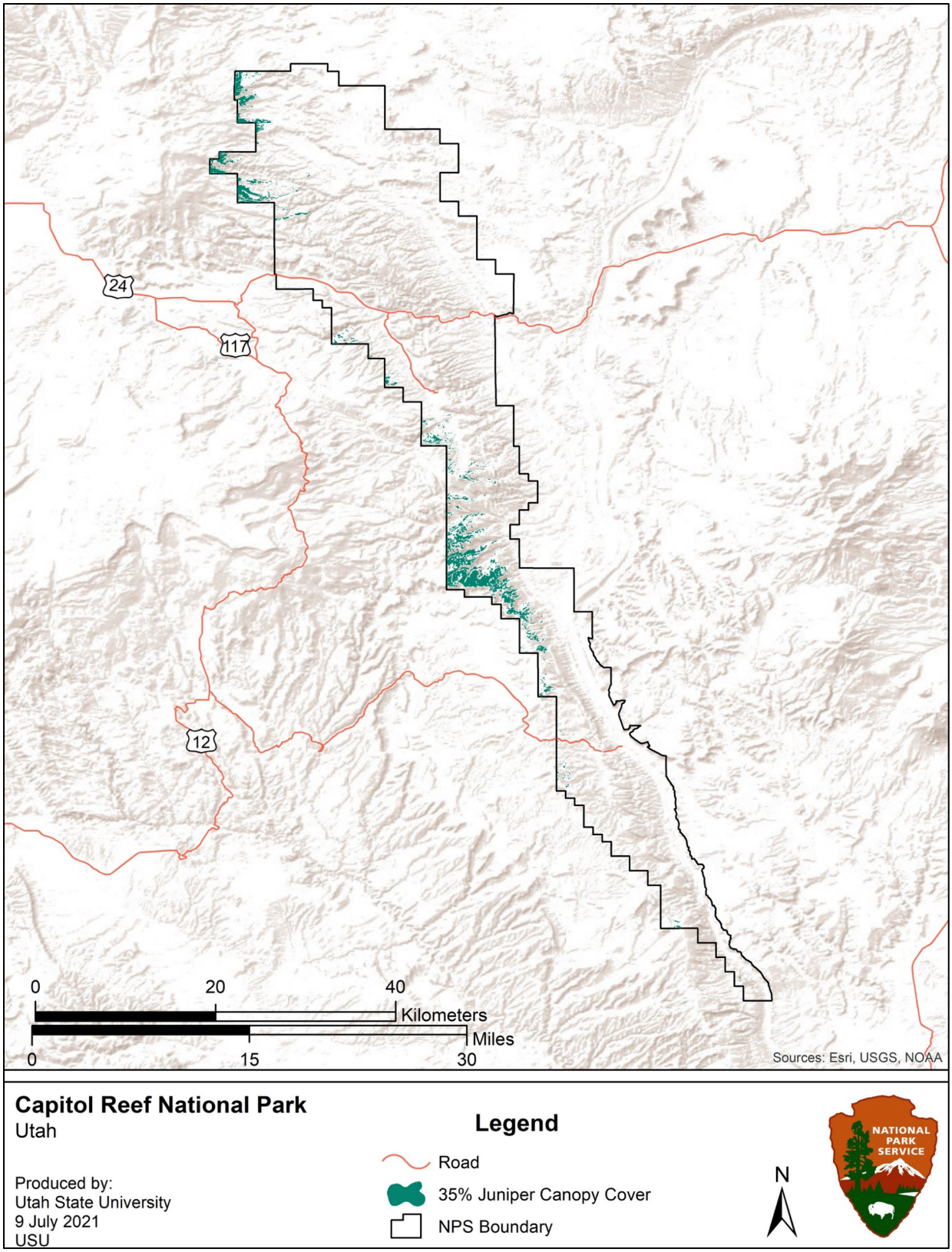


Figure 3.5.4-4. Locations of “fully occupied” (canopy cover equal to or greater than 35%) juniper and pinyon-juniper stands across CARE.

In summary, results of this analysis show that a small portion of CARE features relatively dense pinyon-juniper woodlands that could be considered "fully occupied." These areas do not reach the density level that would be considered overstocked in a forestry sense (i.e., when tree density has reached the stage that growth is limited by competition between trees). However, they may be nearing a condition where risk of woodland loss due to wildfire is increased, and the canopy begins to suppress understory species that may be important to park wildlife. Fewer than 10% of the FIA plots exceeded the SDI threshold of 200. The canopy cover threshold barely exceeded the threshold at 12.5%. The FIA data further demonstrated the dynamic nature of pinyon and juniper expansion and contraction, as some plots increased in density, while others decreased, and only 3.5% of the park's area is in a denser condition. While neither of the tree density measures is ideal, the indicator of condition is supported by two lines of evidence, lending confidence to this finding.

The FIA inventory also provides some evidence of woodland expansion, shown by the existence of FIA plots that have reached a "forest" condition within the past decade due to increased size and density of trees. Our analysis of decadal change in woodland density and cover found evidence that some of CARE's woodlands have been growing denser, but others are reported to have decreased in density, likely due to drought and related disturbances such as insects or pathogens leading to tree mortality. It is possible that some of the variation may represent sampling error rather than actual trend, but even so, the evidence points to there being no substantive change in density or cover.



Left: Mature juniper tree. Right: Juniper "berries," which are modified cones. Image Credits: NPS.

Given the ongoing Southwest megadrought, predicted by climate scientists to persist for as long as several decades (Cook et al. 2015), we see little evidence for rapid densification of park woodlands. The distribution of size classes is well within the reference criteria, and at current growth rates is likely to remain so for years. CARE continues to support populations of pinyon-juniper-dependent birds, suggesting that the woodlands provide a desirable range of habitats. Overall, our assessment of CARE's pinyon-juniper woodland indicators of condition is good, with crown cover increase rated as good/fair (Table 3.5.4-2). Confidence in the tree density and crown cover indicators is low because of uncertainty about the length and intensity of the current drought, which could lead to reduced pinyon and juniper density and crown cover within the park. Confidence in the obligate songbirds

indicator is also low because it is built partly on regionwide trends that may or may not be reflected at the scale of the park, and because the data are available from only two transects. Confidence in the age class distribution indicator is high, as the distribution is likely to be skewed toward an open-canopy, early development condition regardless of the length and intensity of the current drought.

Table 3.5.4-2. Pinyon-juniper woodland condition ratings summary.

Indicator	Condition Rating [1]	Trend	Condition Evaluation
Tree Density	Good	Stable	Fewer than 10% of plots exceeded the SDI threshold, and canopy cover barely exceeded the threshold at 12.5%. Megadrought conditions suggest that density may be likely to decrease in the next 1–3 decades, but if the drought subsides, a trend toward increasing density would be expected. Confidence is low due to uncertainty about the effect of the ongoing drought.
Crown Cover Increase	Good/Fair	Unknown	Mean increase in cover exceeded the reference standard but this increase was attributable to just one plot of 17 measured. There was some evidence of woodland expansion. Megadrought conditions suggest that cover may be likely to decrease in the next 1–3 decades but if the drought subsides, a trend toward increasing cover would be expected. Confidence is low due to uncertainty about the effect of the ongoing drought.
Obligate Songbirds	Good	Unknown	Some changes in songbird population may have occurred, but degradation is not yet measurable. Regionwide trends show steady population size. Confidence at the park level is low due to the small number of woodland transects in the park.
Age-Class Distribution	Good	Stable to Deteriorating	Most of the PJ woodland is in an open, early-development condition and is likely to remain so for some time. While the regionwide trend suggests a likely increase in PJ cover, drought conditions may slow or even reverse that trend. Confidence Is high; the age-class distribution is likely to remain skewed toward open, early-development stands for the next 10–20 years whether or not the current severe drought continues.

[1] See Appendix B, Table B-3, for the 5-level condition rating statements for each indicator.

3.6. Grasslands & Shrublands (Condition Assessment)

3.6.1. Background & Importance

Grass and shrub plant communities (hereafter grasslands/shrublands) in CARE comprise roughly 54,317 ha (134,220 ac), or 37% of the park (Coles et al. 2009). In CARE and across the Colorado Plateau, grasslands/shrublands occur in areas with deep sandy or loamy soils on benches, hillslopes, and valley bottoms, and are characterized by cool-season grasses, including Indian ricegrass (*Stipa hymenoides*) and needle and thread (*Stipa comata*), and warm-season grasses, including galleta (*Hilaria jamesii*), dropseeds (*Sporobolus* species), and blue grama (*Bouteloua gracilis*) (Witwicki 2020). Native shrubs include four-wing saltbush, shadscale (*Atriplex confertifolia*), winterfat (*Krascheninnikovia lanata*), and greasewood (Witwicki 2020). Additionally, biological soil crusts, composed of cyanobacteria, algae, microfungi, mosses, and lichens, play an important role in nutrient cycling and soil retention in the Colorado Plateau's arid and semi-arid grasslands/shrublands. Biological soil crusts, however, are sensitive to even minor disturbances.

Many grasses and shrubs were used by Indigenous peoples of the region. For example, some plants traditionally used by the Hopi include four-wing saltbush, Mormon (Hopi) tea, prickly pear cactus, rabbitbrush, greasewood, and sagebrush, among others (Sucec 2006). Restoring and protecting native plant communities is a fundamental value of park management for both its ecological and ethnographic significance (NPS 2018a).



Upper Cathedral Valley trail through grassland habitat. Image Credit: NPS.

3.6.2. Study Framework

This assessment summarizes plant monitoring data in four former and currently active grazing allotments, all of which have been monitored within the last 10 years. The four allotments are the Hartnet (retired in May 2018), Cathedral (~80% reduction in Animal Unit Months [AUMs] in 1989 and completely retired in 1999), Rock Springs (retired in 1989), and Sandy 3 (active) (NPS 2018b). An AUM is defined as one cow or cow/calf pair grazing for one month (30.4 days) (Fisk and Borthwick 2016). Approximately 68% of the Sandy 3 allotment is accessible to grazing, and 27% of the Hartnet allotment was accessible to grazing while active (Fisk and Borthwick 2016). We relied on two primary data sets: CARE data reported in Fisk and Borthwick (2016), using the Interpreting Indicators of Rangeland Health (IIRH) version 4, developed by Pellant et al. (2005), and NCPN vegetation and soils monitoring data (Witwicki 2020). Note that while we provide a brief overview of methods for IIRH and NCPN data collection, we did not include all details that may interest readers. Please refer to the reports listed above for additional details.

In 2015, the Sandy 3 and Hartnet allotments were surveyed using IIRH version 4 methods described in Pellant et al. (2005) with the results summarized in Fisk and Borthwick (2016) and NPS (2018b). The IIRH data were collected to support the LGTMP (NPS 2018b). The IIRH approach considers three attributes of rangeland health: soil and site stability, hydrologic function, and biotic integrity (Pellant et al. 2005). There are 17 indicators assessed across the three attributes, with some indicators occurring in more than one attribute. In the IIRH approach, the three attributes and 17 indicators are analogous to NRCA indicators and measures, respectively (Table 3.6.2-1). Reference criteria for IIRH indicators are typically found in reference sheets that are part of the Natural Resources Conservation Service's (NRCS) Ecological Site Descriptions (ESD), if available (Pellant et al. 2005). ESDs are not explicitly spatial but are linked to NRCS soil survey map unit (SMU) components. Because many reference criteria are qualitative and there are multiple ESD and SMU descriptions surveyed during the IIRH effort, we included generic reference criteria outlined in Pellant et al. (2005). Pellant et al. (2005) defines departure from reference conditions as none to slight, slight to moderate, moderate, moderate to extreme, and extreme to total. These five categories are analogous to the NRCA condition rating statements of good, good/fair, fair, fair/poor, and poor (Appendix B, Table B-4).

In response to the completion of CARE's LGTMP in 2018, the park continued monitoring some of the IIRH plots using the BLM Assessment, Inventory, and Monitoring (AIM) protocol (Taylor et al. 2014). Core AIM data include bare ground, vegetation composition, vegetation height, plant canopy gaps, non-native invasive plants, and plant species of management concern. AIM data were collected in 2019 and 2020; however, we could not obtain these data.

Table 3.6.2-1. Study details for the grasslands/shrublands condition assessment. Note: IIRH = Interpreting Indicators of Rangeland Health (IIRH) version 4; NCPN = Northern Colorado Plateau Inventory & Monitoring Network; NPS ARD = National Park Service Air Resources Division data sources.

Indicator of Condition				Measure	Reference Criteria for Measure
Biotic Integrity	**Soil & Site Stability**	**Hydrologic Function**	**Nitrogen**		
IIRH	–	–	–	Functional/ structural groups	Functional/structural groups & number of species in each group closely match that expected for the site.
IIRH	–	–	–	Dead/dying plants or plant parts	Plant mortality and decadence match that expected for the site.
IIRH	–	–	–	Annual production	Exceeds 80% of potential production for the site based on recent weather.
IIRH	–	–	–	Invasive plants	If present, composition of species matches that expected for the site.
IIRH	–	IIRH	–	Litter cover and depth	Amount is what is expected for the site potential and weather.
IIRH	–	–	–	Vigor	Capability to produce seed or vegetative tillers is not reduced relative to recent climatic conditions.
–	IIRH	IIRH	–	Rills	Current or past formation of rills as expected for the site.
–	IIRH	IIRH	–	Water flow patterns	Matches what is expected for the site, minimal evidence of current or past soil deposition and erosion.
–	IIRH	IIRH	–	Pedestals and/or terracettes	Current or past evidence of pedestaled plants or rocks as expected for the site. Terracettes are uncommon or absent.
–	IIRH	IIRH	–	Bare ground	Amount and size of bare areas match that expected for the site.

Table 3.6.2-1 (continued). Study details for the grasslands/shrublands condition assessment. Note: IIRH = Interpreting Indicators of Rangeland Health (IIRH) version 4; NCPN = Northern Colorado Plateau Inventory & Monitoring Network; NPS ARD = National Park Service Air Resources Division data sources.

Indicator of Condition				Measure	Reference Criteria for Measure
Biotic Integrity	**Soil & Site Stability**	**Hydrologic Function**	**Nitrogen**		
–	IIRH	IIRH	–	Gullies	Matches what is expected for the site; drainages are represented as natural stable channels; vegetation common and no signs of erosion.
–	IIRH	–	–	Wind-scoured/ depositional areas	Matches what is expected for the site.
–	IIRH	–	–	Litter movement	Matches that expected for the site with a uniform distribution of litter.
IIRH	IIRH	IIRH	–	Soil surface resistance to erosion	Matches that expected for the site. Surface soil is stabilized by organic matter decomposition products and/or biological crust.
IIRH	IIRH	IIRH	–	Soil surface loss and degradation	Soil surface horizon intact. Soil structure and organic matter content match that expected for site.
IIRH	IIRH	IIRH	–	Compaction layer	Matches that expected for the site; none to minimal, not restrictive to water movement and root penetration.
–	–	IIRH	–	Effects of plant community composition & distribution on infiltration	Infiltration and runoff are not affected by any changes in plant community composition and distribution. Any changes in infiltration and runoff can be attributed to other factors.
NCPN	–	NCPN	–	Total cover	≥12%
NCPN	–	–	–	Perennial grass cover	≥8–9%

Table 3.6.2-1 (continued). Study details for the grasslands/shrublands condition assessment. Note: IIRH = Interpreting Indicators of Rangeland Health (IIRH) version 4; NCPN = Northern Colorado Plateau Inventory & Monitoring Network; NPS ARD = National Park Service Air Resources Division data sources.

Indicator of Condition				Measure	Reference Criteria for Measure
Biotic Integrity	**Soil & Site Stability**	**Hydrologic Function**	**Nitrogen**		
NCPN	–	–	–	Cool-season grass cover	≥2–3%
NCPN	–	–	–	Warm-season grass cover	≥2–3%
NCPN	–	–	–	Shrub cover	2–15%
NCPN	–	–	–	Shrub density	2,000–50,000 shrubs/ha
NCPN	–	–	–	Frequency of non-native species	<1%
–	NCPN	NCPN	–	Biological soil crust cover	≥2%
–	NCPN	NCPN	–	Bare soil cover	≤ 1%
–	NCPN	NCPN	–	Soil-stability rating	Average surface soil aggregate stability is ≥ Class 5.
–	NCPN	NCPN	–	Canopy gap size	<100 cm
–	–	–	NPS ARD	Nitrogen wet deposition	≤1 kg/ha/yr

The NCPN has surveyed plants and soils, using 11 measures (refer to Table 3.6.2-1), in the Hartnet, Cathedral, and Rock Springs allotments since 2007 (Witwicki 2020). NCPN data were analyzed, and condition was reported at the measure level (e.g., total cover, soil stability, etc.). For consistency with the NRCA framework, we rolled-up condition ratings to three indicator of condition levels (i.e., biotic integrity, soil and site stability, and hydrologic function) to match the IIRH structure. Reference criteria were based primarily on expert opinion because of the paucity of data available in the arid West due to impacts from widespread historical livestock grazing (Witwicki 2020; NPS, D. Witwicki, NRCA project manager, e-mail communication, 26 July 2021).

Lastly, we included the NPS ARD nitrogen wet deposition data (NPS ARD 2021a), which is monitored across the United States as part of the National Atmospheric Deposition Program/National Trends Network (NADP/NTN).

Using NCPN and IIRH data, we assigned a condition to the indicators of soil and site stability, hydrologic function, and biotic integrity for each of the four allotments separately. Therefore, the level of inference for the NCPN and IIRH results are restricted to the allotments and not necessarily to the grasslands/shrublands park-wide, whereas the indicator of nitrogen wet deposition was assessed park-wide for arid and semi-arid grasslands.

3.6.3. Data & Methods

There were 45 IIRH plots surveyed in the Hartnet allotment and 40 IIRH plots surveyed in the Sandy 3 allotment. Approximately half of these were surveyed in May and June 2015 while the remaining plots were surveyed in September and October 2015 (NPS 2018b) (Figure 3.6.3-1). Plots were approximately 0.4 ha (1.0 ac) and, comprised of three parallel 50-m (164-ft) transects separated by 25 m (82 ft) (NPS 2018b) (see Pellant et al. 2005 and NPS 2018b for more details).

The NCPN summarized more than a decade (2009–2018) of vegetation and soils data in the Hartnet, Cathedral, and Rock Springs allotments, which were stratified by grassland type (i.e., deep or rocky grasslands) (Witwicki 2020). Both deep and rocky grasslands were sampled on the Hartnet allotment, but only deep grasslands were sampled in the Cathedral and Rock Springs allotments because rocky grasslands were too limited to sample adequately (Witwicki 2020).

Deep grasslands are characterized by deep alkali sandy loams on dissected alluvial fans or on mesas and valleys, or by deep sands on dunes and sand sheets (Witwicki 2020). Rocky grasslands are characterized by deep stony loams on top of structural benches, valley sides, or steep remnant hillsides. Ecological-site groups and grazing histories were combined, resulting in three strata: Cathedral/Rock Springs deep grasslands, Hartnet deep grasslands, and Hartnet rocky grasslands (Witwicki 2020). “Deep grasslands in the two retired allotments were combined in the sampling design because most of the grazing in the Cathedral allotment retired at the same time as the Rock Springs allotment, and ecological conditions were similar in both allotments” (Witwicki 2020).

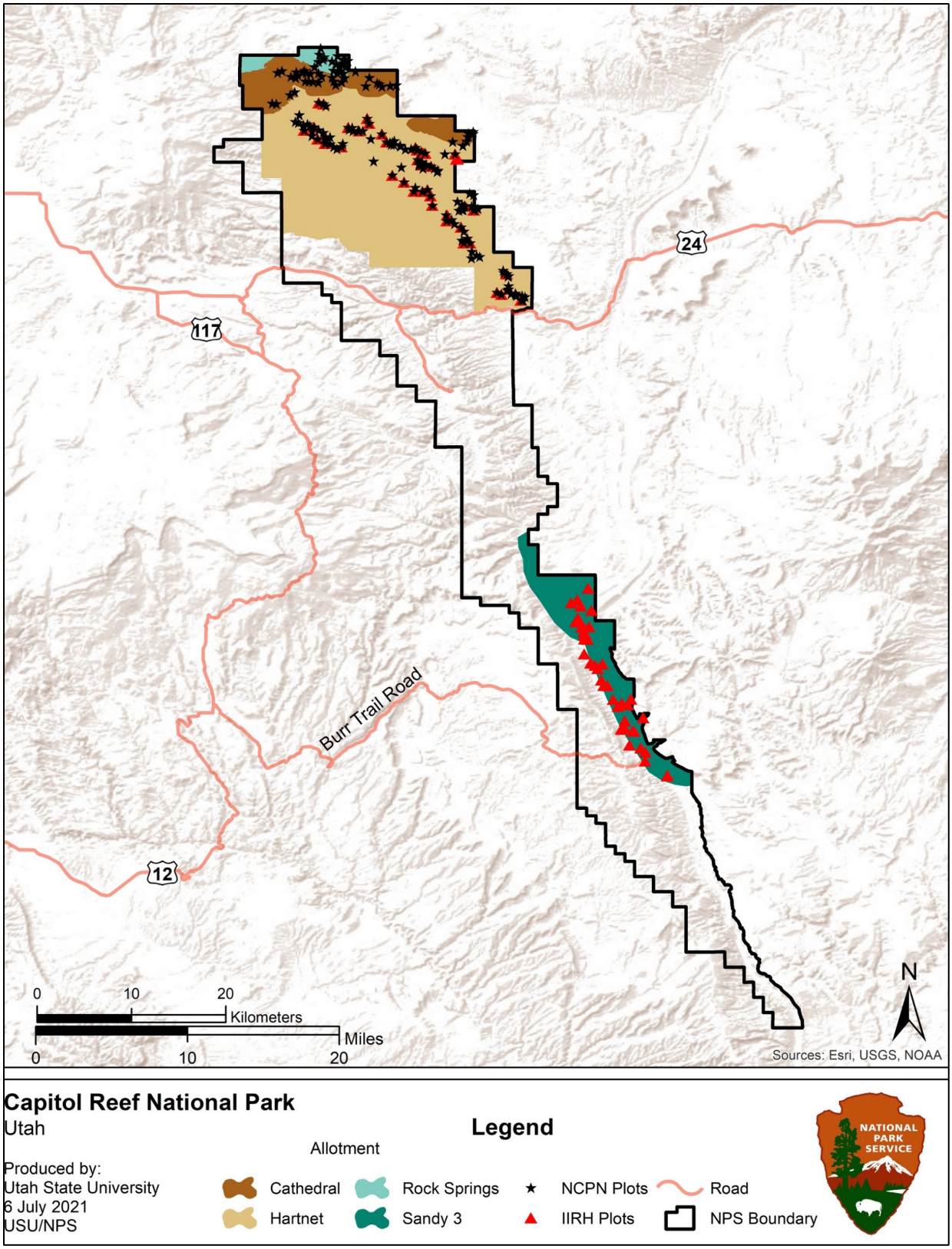


Figure 3.6.3-1. Grasslands-shrublands monitored in CARE.

NCPN plots were the same size and shape as IIRH plots, with three, 50-m (164-ft) transects spaced 25 m (82 ft) apart. There were 180 NCPN plots (60 in each stratum), which were sampled on a 5-year repeat basis. NCPN based current conditions and trends on 2009 to 2018 data, except for non-native plant frequency, which was based on 2011 to 2018 data. We reported the most recent data (i.e., 2018, which was a drought year) for each stratum (refer to Witwicki et al. 2017 and Witwicki 2020 for more details). Note, however, that condition was based on overall results from 2009 to 2018.

A 5-year average (2014–2018) of nitrogen wet deposition was estimated for CARE based on interpolated data from more distant monitors (NPS ARD 2021a). Data were obtained from the NPS ARD condition dashboard website (NPS ARD 2021b).

3.6.4. Results & Discussion

The IIRH evaluations revealed that 56.4% to 69.3% of all plots in the Sandy 3 allotment were in a state of moderate or moderate to extreme departure from reference criteria in 2015 (Figure 3.6.4-1). The primary factors contributing to fair/poor soil and site stability conditions (59% of the plots were in moderate and moderate to extreme departure) were low resistance to erosion, high amounts of bare ground, water flow patterns (as evidenced by pedestals and/or terracettes, gullies, and rills), and soil loss. Invasive plants, substantial departure from expected species composition and structure, and litter contributed most to the fair/poor condition rating (69.3% of the plots were in moderate and moderate to extreme departure) for biotic integrity. Hydrologic function was fair/poor (56.4% of the plots were in moderate and moderate to extreme departure), owing largely to poor resistance of the soil surface to erosion, plant community composition and structure that failed to reduce infiltration and runoff, and the presence of rills. Because the condition is based on only one year of data (2015), the trend is unknown and confidence in the condition rating is low.

NCPN analyzed data for the last 10 years of grazing in the Hartnet allotment that indicated fair/poor conditions for all three indicators. IIRH data show that 34.9% of plots were in moderate and 30.2% of plots were in moderate to extreme departure from reference criteria for soil and site stability (Figure 3.6.4-2). Of the measures of soil and site stability, soil surface loss or degradation; bare ground; soil surface resistance to erosion; and wind-scoured, blowout, or depositional areas contributed the most to the moderate and moderate to extreme departure from reference criteria (NPS 2018b).

NCPN data show improving trends for all four soil and site stability measures in both deep (Table 3.6.4-1) and rocky grasslands (Table 3.6.4-2). Rocky grasslands were in slightly better condition than deep grasslands, perhaps because the rockier substrate limited cattle access. Confidence in the condition ratings for all three indicators is medium because of wide confidence intervals, limited historical data, and a relatively short-term data set (Witwicki 2020).

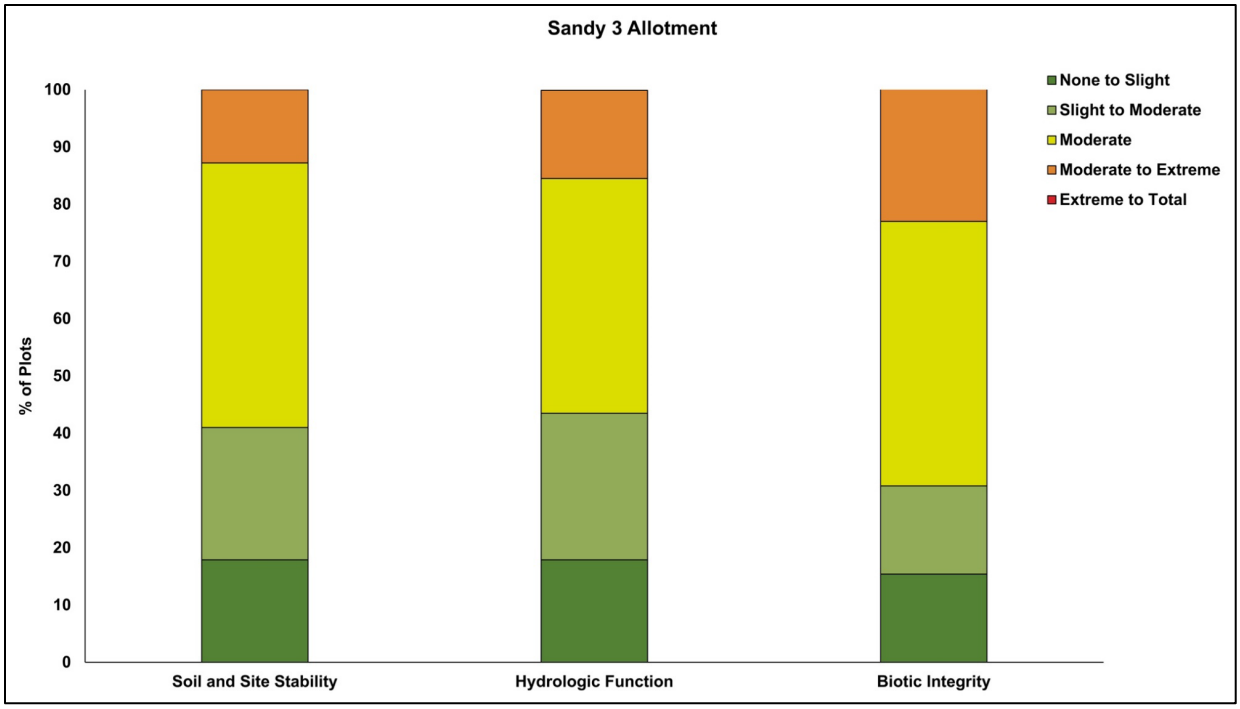


Figure 3.6.4-1. The proportion of IIRH plots in the Sandy 3 allotment by departure class for soil and site stability, hydrologic function, and biotic integrity indicators of condition.

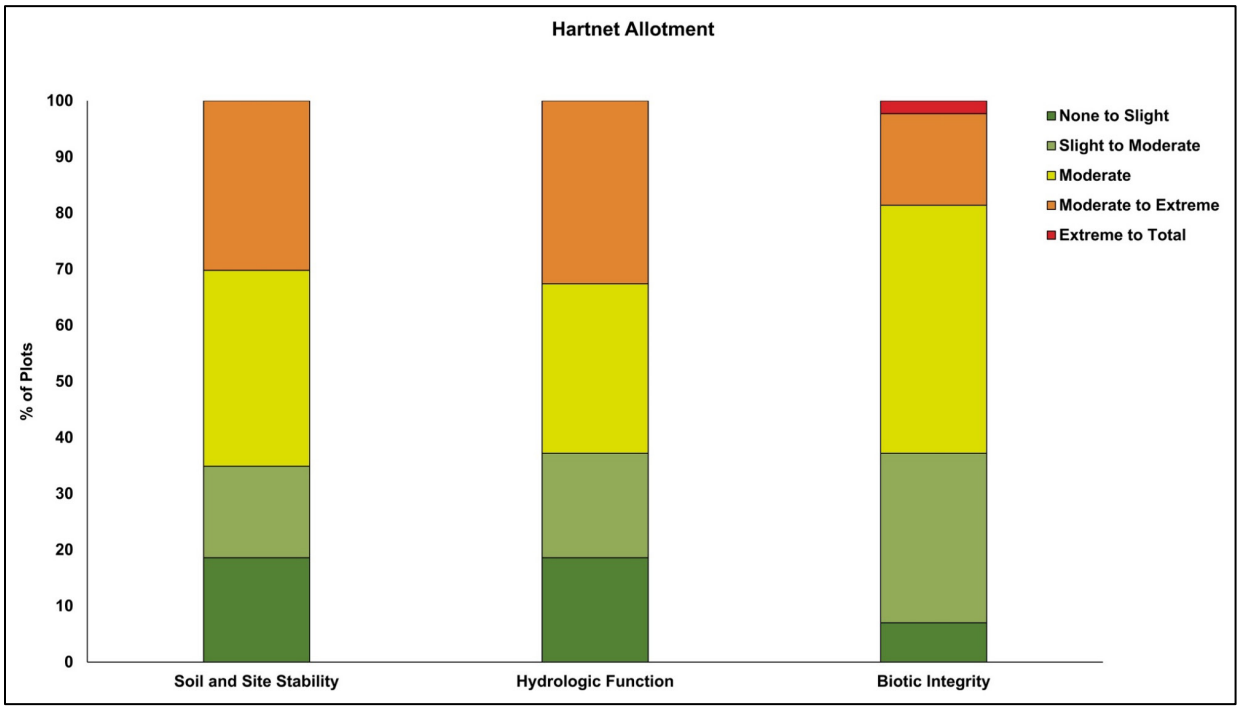


Figure 3.6.4-2. The proportion of IIRH plots in the Hartnet allotment by departure class for soil and site stability, hydrologic function, and biotic integrity indicators of condition.

Table 3.6.4-1. Summary of Witwicki (2020) data for Hartnet deep grasslands (2009–2018).

Indicator	Measure	2018 Mean	2018 95% Confidence Interval	Condition	Trend
Biotic Integrity	Perennial grass cover	2.9%	3.2–14.1	Fair	Deteriorating
	Cool-season grass cover	0.6%	0.2–1.4	Poor	Deteriorating
	Warm-season grass cover	2.6%	0.3–8.0	Fair	Stable
	Shrub cover	2.3%	0.6–6.2	Good	Deteriorating
	Shrub density	7,016 shrubs/ha	575–44,653	Good	Stable
	Frequency of non-native species	9.4%	0.0–85.4	Fair	Improving
Biotic Integrity, Hydrologic Function	Total cover	7.0%	3.2–14.1	Fair	Deteriorating
Soil and Site Stability, Hydrologic Function	Biological soil crust cover	1.5%	0.0–9.1	Poor	Improving
	Bare soil cover	1.9%	0.0–7.5	Fair	Improving
	Soil stability rating	3.1	1.5–4.5	Fair	Improving
	Canopy gap size	145 cm	45.0–294.0	Fair	Improving

Table 3.6.4-2. Summary of Witwicki (2020) data for Hartnet rocky grasslands (2009–2018).

Indicator	Measure	2018 Mean	2018 95% Confidence Interval	Condition	Trend
Biotic Integrity	Perennial grass cover	2.1%	0.7–4.3	Fair	Deteriorating
	Cool-season grass cover	0.8%	0.1–2.5%	Poor	Deteriorating
	Warm-season grass cover	1.3%	0.4–3.3%	Poor	Deteriorating
	Shrub cover	2.7%	0.8–5.7	Good	Deteriorating
	Shrub density	10,408 shrubs/ha	2,813–26,025	Good	Improving
	Frequency of non-native species	3.1%	0.0–33.4	Fair	Stable

Table 3.6.4-2 (continued). Summary of Witwicki (2020) data for Hartnet rocky grasslands (2009–2018).

Indicator	Measure	2018 Mean	2018 95% Confidence Interval	Condition	Trend
Biotic Integrity, Hydrologic Function	Total cover	6.6%	3.5–10.1	Fair	Deteriorating
Soil and Site Stability, Hydrologic Function	Biological soil crust cover	2.0%	0.0–8.1	Good	Improving
	Bare soil cover	0.3%	0.0–1.5	Good	Improving
	Soil stability rating	4.0	2.8–5.2	Fair	Improving
	Canopy gap size	102 cm	42.0–199.0	Fair	Improving

Hydrologic function in the Hartnet allotment also rated fair/poor because 62.8% of the plots were rated as moderate (30.2%) or moderate to extreme (32.6%) departure from reference criteria (Figure 3.6.4-2). The measures that contributed most to the fair/poor condition were soil surface loss or degradation, bare ground, water flow patterns, soil surface resistance to erosion, and plant community composition and distribution relative to infiltration and runoff (NPS 2018b). Hydrologic function was best in areas where biological soil crusts were well-developed and vegetation communities were intact (NPS 2018b). As described above, NCPN data show improving trends in biological soil crust cover, soil stability, bare soil cover, and canopy gap size in both deep and rocky grasslands. However, these measures were mostly rated as fair. Total plant cover was the only measure of hydrologic function that deteriorated. Confidence in the condition ratings for hydrologic function is medium because of wide confidence intervals, limited historical data, and a relatively short-term data set (Witwicki 2020).

Biotic integrity in the Hartnet allotment was rated as fair/poor because 62.8% of plots were rated as moderate (44.2%), moderate to extreme (16.3%), or extreme to total (2.3%) departure from reference criteria in 2015 (Figure 3.6.4-2). The measures that contributed most to the fair/poor condition were soil resistance to erosion, soil loss or degradation, functional/structural groups, plant mortality, annual production, invasive plants, and plant reproductive capability (NPS 2018b). Non-native plant frequency, total plant cover, and perennial grass cover indicate fair condition, while shrub cover and shrub density indicate good condition. Cool- and warm-season grass covers were rated as moderate to poor depending on grassland type. NCPN trends for most measures of biotic integrity deteriorated. Confidence in the condition ratings is medium because of wide confidence intervals, limited historical data, and a relatively short-term data set (Witwicki 2020).

Data from the Rock Springs and Cathedral allotments while they were actively grazed are limited, but BLM line transects in the Cathedral allotment compared to NCPN data suggest that this area has recovered somewhat from past grazing (Witwicki 2020). For example, BLM data showed that Indian ricegrass, a native cool-season species, increased in frequency after 1989, “with 0–2 individuals counted in each transect in 1979–1989 and 29–46 individuals counted in each transect by 1996” (Witwicki 2020). Photo documentation presented in McEwen (1999) (as cited in Witwicki 2020) supports this. Stable trends for some measures (e.g., shrub density, perennial grass cover, cool-season grass cover) in these allotments suggest that recovery from grazing may have occurred prior to NCPN monitoring (Table 3.6.4-3; Witwicki 2020). Confidence in the condition ratings for all three indicators in both allotments is medium because of wide confidence intervals, limited historical data, and a relatively short-term data set (Witwicki 2020).

Table 3.6.4-3. Summary of Witwicki (2020) data for Cathedral/Rock Springs deep grasslands (2009–2018).

Indicator	Measure	2018 Mean	2018 95% Confidence Interval	Condition	Trend
Biotic Integrity	Perennial grass cover	6.5%	2.7–11.9	Good	Stable
	Cool-season grass cover	2.1%	0.3–6.0	Fair	Stable
	Warm-season grass cover	4.1%	1.4–8.7%	Good	Improving
	Shrub cover	2.6%	0.8–6.8	Good	Deteriorating
	Shrub density	3,716 shrubs/ha	540–10,730	Good	Stable
	Frequency of non-native species	0.1%	0.0–0.7	Good	Improving
Biotic Integrity, Hydrologic Function	Total cover	10.6%	5.2–18.0	Good	Stable
Soil and Site Stability, Hydrologic Function	Biological soil crust cover	12.0%	0.03–39.5	Good	Improving
	Bare soil cover	0.6%	0.0–4.0	Good	Improving
	Soil stability rating	5.0	3.9–5.9	Good	Improving
	Canopy gap size	74 cm	31–152	Good	Improving

According to LANDFIRE, CARE supports 41,689 ha (103,016 ac) of nitrogen-sensitive semi-arid and arid grasslands, which together represent 43% of the park (E&S Environmental Chemistry, Inc. 2009). Sullivan (2016a,b) rated ecosystems in CARE as highly sensitive to nitrogen enrichment relative to all NPS Inventory & Monitoring parks, particularly for arid and semi-arid grasslands.

The five-year (2014–2018) mean nitrogen deposition was estimated to be between 0.7 and 1.6 kg/ha/yr, which is rated as fair condition (NPS ARD 2021b). Although the threshold for good condition is <1.0 kg/ha/yr, NPS ARD bases condition on the maximum value to maintain the highest level of protection. Combined, wet and dry deposition was estimated to be between 2.0 and 3.9 kg/ha/yr, which exceeds critical loads for ecosystem health (NPS ARD 2021b). The effects of nitrogen enrichment may include disruption of soil nutrient cycling and reduced plant diversity. Nitrogen may also increase the growth rate of invasive species in physically disturbed areas (NPS, M. Bell, comments to draft evaluation, 16 August 2021). Because there are no on-site or nearby monitors, nitrogen deposition was estimated from more distant monitors, which precludes trend estimates and warrants a medium confidence level in the condition rating (NPS ARD 2021b).

A summary of the grassland/shrubland soil and site stability, hydrologic function, and biotic integrity indicators of condition ratings by allotment is presented in Table 3.6.4-4. The nitrogen wet deposition indicator of condition rating is presented in Table 3.6.4-4 for the entire park.

Of the four allotments, Rock Springs and Cathedral were nearest to the good reference criteria, while the Sandy 3 and Hartnet allotments departed substantially from good conditions. The Hartnet allotment was retired in 2018 as the last year of monitoring data were collected. In contrast, both the Rock Springs and Cathedral allotments have been retired since 1989 and 1999, respectively, allowing time for recovery. The good conditions for the Cathedral and Rock Springs allotments several decades post-grazing suggests that the Hartnet allotment may recover from the effects of grazing, but while grazing continues in Sandy 3, it is unlikely that current conditions will change. Recovery, however, depends on many factors.

The NCPN's conceptual model of dryland systems (Appendix A-3 in O'Dell et al. 2005) summarizes the key drivers, stressors, and degradation processes associated with each stressor. The conceptual model stressors that pertain to CARE include climate change, air pollution, visitor use, invasive and exotic plants, adjacent land use, and livestock grazing. Because there is little evidence of past fire within CARE due to lack of large stands of fire-sustaining vegetation (NPS n.d), we did not include fire exclusion as a stressor. However, the invasion of cheatgrass and other non-native plants may increase fire risk to the park's plant communities, which are not fire adapted (Bradley et al. 2018).

Table 3.6.4-4. Grassland/shrubland condition ratings summary.

Indicator	Allotment	Condition Rating [1]	Trend [2]	Condition Evaluation
Soil and Site Stability	Sandy 3	Fair/Poor	Unknown	The condition is fair/poor because 59% of plots were moderate or moderate to extreme departure from reference criteria. IIRH data were collected in 2015 only, so confidence is low, and trend is unknown.
	Hartnet	Fair/Poor	Variable	The condition is fair/poor because 65.1% of IIRH plots were moderate or moderate to extreme departure from reference criteria. NCPN data indicate fair condition in deep grasslands and good/fair condition in rocky grasslands, with mixed trends. Confidence is medium due to wide confidence intervals and a short-term data set.
	Rock Springs, Cathedral	Good	Improving	The four measures were in good condition based on NCPN data. Trend improved for all four measures. Confidence in the condition rating is medium because of wide confidence intervals and a short-term data set.
Hydrologic Function	Sandy 3	Fair/Poor	Unknown	The condition is fair/poor because 56.4% of plots were moderate or moderate to extreme departure from reference criteria. IIRH data were collected in 2015 only, so confidence is low, and trend is unknown.
	Hartnet	Fair/Poor	Improving	The condition is fair/poor because 62.8% of the plots were moderate or moderate to extreme departure from reference criteria. NCPN data show improving trends in four measures. Confidence is medium because of wide confidence intervals and a short-term data set.
	Rock Springs, Cathedral	Good	Improving	The five measures were in good condition based on 2009–2019 NCPN data. Trend improved for 4 of 5 measures. Confidence in the condition rating is medium because of wide confidence intervals and a short-term data set.

[1] See Appendix B, Table B-4, for the 5-level condition rating statements for each indicator.

[2] Trends are based on NCPN data only.

Table 3.6.4-4 (continued). Grassland/shrubland condition ratings summary.

Indicator	Allotment	Condition Rating [1]	Trend [2]	Condition Evaluation
Biotic Integrity	Sandy 3	Fair/Poor	Unknown	The condition is fair/poor because 69.3% of plots were moderate or moderate to extreme departure from reference criteria. IIRH data were collected in 2015 only, so confidence is low, and trend is unknown.
	Hartnet	Fair/Poor	Deteriorating	The condition is fair/poor because 62.8% of the plots were moderate, moderate to extreme, or extreme to total departure from reference criteria. The overall trend is deteriorating. Confidence in the condition rating is medium because of wide confidence intervals and a short-term data set.
	Rock Springs, Cathedral	Good	Stable to Improving	Six measures of biotic integrity were in good condition (2009–2019 NCPN data), with one in fair condition. Trends were stable to improving. Confidence in the condition rating is medium because of wide confidence intervals and a short-term data set.
Nitrogen wet deposition	Park-wide	Fair	Unknown	Wet nitrogen deposition is in fair condition for ecosystem health based on the 5-year average (2014–2018) range of 0.7–1.6 kg/ha/yr. Trend is unknown because there are no on-site or nearby monitoring stations. Confidence is medium because estimates were interpolated from more distant monitors.

[1] See Appendix B, Table B-4, for the 5-level condition rating statements for each indicator.

[2] Trends are based on NCPN data only.

Visitors hiking, especially off-trail, or livestock trailing can introduce non-native plant seeds, in addition to disturbing sensitive plant communities, particularly for biological soil crusts (NPS 2018b). The Lake Mead IPMT helps to monitor and control non-native plants along these trails (NPS 2018a). Trampling of native vegetation and disturbed soils caused by livestock trailing encourages establishment and growth of non-native and invasive plants. Six non-native plants were detected during NCPN monitoring: Russian thistle, halogeton, salsify (*Tragopogon dubius*), cheatgrass, African mustard (*Malcolmia africana*), and tamarisk species (Witwicki 2020). However, grazing has been mostly phased out of CARE and currently occurs on only a small portion of the park.

Air pollutants may also have a negative impact on plant growth. According to Weber et al. (2021) "many air pollutants, such as O_3 and NO_x, affect the metabolic function of the leaves and interfere with net carbon fixation by the plant canopy." Air pollution, in combination with other stresses, such as water loss, may lead to changes in plant community composition (Weber et al. 2021), although the park's ozone-sensitive species are not in the grassland/shrubland plant communities. They are wetland associates and non-native plants found elsewhere throughout the park (NPSpecies 2021).



Hikers may inadvertently carry unwanted plant seeds on their shoes. Image Credit: NPS / REID ELEM.

Water is the most limiting factor in arid and semi-arid systems, and NCPN staff are studying how climate data can be used to identify pivot points, or thresholds for which changes in one variable (e.g., water availability) lead to above average or below average plant growth in different plant communities (Thoma et al. 2018). Pivot points can help managers understand the long-term effects of a changing climate, as well as the short-term effects within a season. Using satellite imagery to determine plant productivity, Thoma et al. (2018) identified pivot points for cumulative annual actual evapotranspiration (204 ± 2 mm), cumulative annual precipitation (214 ± 2 mm), average annual soil moisture (6 ± 0.3 mm), and cumulative annual water deficit (540 ± 7 mm) for grasslands

communities across six national parks on the Northern Colorado Plateau, including CARE. Thoma et al. (2018) found that all relationships between pivot points and productivity were significant except for soil moisture. In grassland systems of the Northern Colorado Plateau, 97% of precipitation is returned to the atmosphere through evapotranspiration, and there is very little soil infiltration in dryland ecosystems (depending on soil type) (Thoma et al. 2018). Understanding pivot points in the grasslands/shrublands of CARE's allotments will help managers better understand how annual climate conditions influence plant productivity, which may change as grazing allotments recover.

3.7. Rare Plants (Gap Analysis)

3.7.1. Background & Importance

CARE contains high plant diversity and has a large concentration of locally rare and endemic plants (Coles et al. 2009). Fertig and Reynolds (2012) compared the number of rare and endemic plant taxa across national parks in Utah and found that CARE ranked fourth highest in rare taxa, third in endemic taxa, and second when considering all vascular plant species. According to CARE's annotated checklist of plants and subsequent updates, there are 28 locally endemic and 110 regionally endemic taxa in the park (Fertig 2009; Fertig et al. 2012). Locally endemic species are found in very limited areas, while regionally endemic species are more widespread on the Colorado Plateau (Fertig 2009). Rare and endemic species represent about 18% of the park's total number of plant species (Fertig 2009). The list of rare and endemic plants includes six species listed by the USFWS as threatened or endangered (NPSpecies 2021) and one species that is in recovery status (i.e., Maguire daisy [*Erigeron maguirei*]) (USFWS 2010). The federally endangered Despain's cactus (*Pediocactus despainii*) is suspected to occur in CARE but has not been confirmed (NPSpecies 2021). Although no rare, threatened, or endangered plants were mentioned in CARE's ethnographic overview, plants in general were traditionally used for food, medicine, ceremonies, decorations, baskets, and other materials (Sucec 2006).



CARE's geology, soils, and climate support the park's high plant diversity. Cassidy Arch is visible in the background in the Wingate Sandstone. Image Credit: NPS / D. POPOVIC.

3.7.2. Status of Knowledge

In 1997, CARE staff received a Canon grant to survey rare plants in and around the Fruita area of the park (Clark and Clark 1999). The objectives were to conduct intensive surveys (1997–1998) within this high-use area and to develop monitoring protocols that would allow managers to detect changes in populations caused by visitor impacts (Clark and Clark 1999). In 1999, the BLM, CARE, the Dixie NF, and the Fishlake NF formed an Interagency Rare Plant Team to inventory rare plants across the different agencies (Clark and Tait 2007; USDA and USDOI 2006). These surveys occurred from 1998 to 2003. And in 2019 and 2021, the Arboretum at Flagstaff, in cooperation with CARE, conducted surveys for Wright fishhook cactus (*Sclerocactus wrightiae*, USFWS endangered), Winkler cactus (*Pediocactus winkleri*, USFWS threatened), and Last Chance townsendia (*Townsendia aprica*, USFWS threatened), in the park's most recently retired grazing allotment as part of a Focused Condition Assessment (Borthwick and Livensperger 2018; Murray 2020).

From 2013 to present, CARE staff have also conducted annual demographic monitoring of Wright fishhook and Winkler cactus at 459 plots in 37 different localities, with the goal of understanding population dynamics and response to disturbance (NPS, C. Livensperger, plant ecologist, comments to draft evaluation, 15 June 2021). Hope Hornbeck (contactor, Manzanita Botanical) is conducting a population viability analysis using this long-term data set, which includes projected population trends for each species with and without cattle disturbance. Because these data are currently being analyzed and will be reported on separately, they are not included in this evaluation (NPS, C. Livensperger, plant ecologist, manager-scientist meeting, 26 August 2021).

Per CARE staff request, this evaluation focuses on summarizing a subset of the rare plants data (NPS, S. Borthwick (biologist) and C. Livensperger (plant ecologist), NRCA scoping meeting, 19 & 22 January 2021) included in CARE's rare plants Access database and ArcGIS geodatabase (NPS, S. Borthwick, biologist, Access database and ArcGIS geodatabase, 4 February 2021). A summary of the number of known sites and plant abundance, site quality, and disturbance history for six USFWS listed species, 14 NPS sensitive species, and six species removed from the NPS sensitive plant species list is shown in Table 3.7.2-1 using CARE's databases (NPS, S. Borthwick, biologist, Word document, 4 February 2021). CARE managers were also interested in how populations in the park compare to populations within the surrounding area.

Table 3.7.2-1. Summary of rare plant species of concern found in and around CARE.

Group	Common Name	Scientific Name	# CARE Sites (# Sites Outside CARE)	# Total Estimated Sites [3]	Years Monitored in CARE	CARE Sites Revisited
Threatened (T) & Endangered (E)	Barneby reed-mustard (E)	*Schoenocrambe (Hesperidanthus) barnebyi* [1]	14 (3)	1–5	1997, 2004, 2005	0
	Jones cycladenia (T)	*Cycladenia humilis v. jonesii* [2]	3 (3)	Unknown	1997, 2002, 2010, 2020	1
	Last Chance townsendia (T)	*Townsendia aprica* [1]	53 (163)	21–80	1998–2005, 2010–2012, 2015–2016	10
	Ute ladies-tresses (T)	*Spiranthes diluvialis* [1]	None Known	21–80	Not Monitored	–
	Wright fishhook cactus (E)	*Sclerocactus wrightiae* [1]	81 (19)	21–80	2011–2013, 2015–2019	16
	Winkler cactus (T)	*Pediocactus winkleri* [1]	99 (50)	1–20	1998–1999, 2001, 2004, 2008, 2010–2013, 2015–2017, 2019	22
NPS Sensitive Species	Abajo daisy	*Erigeron abajoensis* [1]	1 (0)	1–20	2001	0
	Alcove bog-orchid	*Platanthera (Habenaria) zothecina* [2]	4 (0)	21–80	2013, 2017	0
	Bicknell milkvetch	*Astragalus consobrinus* [1]	0 (5)	21–300	Not monitored	–
	Bolander's camissonia	*Camissonia bolanderi* [1]	0 (0)	Unknown	Not monitored	–
	Cataract gilia	*Aliciella latifolia* spp. *Imperialis* [1]	0 (0)	Unknown	Not monitored	–
	Harrison's milkvetch	*Astragalus harrisonii* [1]	25 (0)	Unknown	1997–1998, 2002, 2017, 2020	1
	Henrieville woody-aster	*Xylorhiza confertifolia* [1]	0 (1)	Unknown	Not monitored	–
	Maguire daisy	*Erigeron maguirei* [1]	82 (19)	6–20	1997–2002, 2004–2006	3
	Mussentuchit gilia	*Aliciella tenuis* [1]	0 (0)	1–20	Not monitored	–
	Osterhout's cryptanth	*Cryptantha osterhoutii* [2]	0 (0)	21–80	Not monitored	–
	Pinnate spring-parsley	*Cymopterus beckii* [1]	34 (30)	6–20	1997, 2000–2002	1
	Rabbit Valley gilia	*Aliciella caespitosa* [1]	0 (0)	6–20	Not monitored	–

[1] Locally endemic (species whose entire global range is restricted to an area of less than 16,500 km^2 [6,370 mi^2] or 1° of latitude by 2° of longitude) (Fertig 2009).

[2] Regionally endemic (species with a global range of 16,500–250,000 km^2 [6,370–96,526 mi^2], or about the size of Wyoming) (Fertig 2009).

[3] NatureServe (2021).

Table 3.7.2-1 (continued). Summary of rare plant species of concern found in and around CARE.

Group	Common Name	Scientific Name	# CARE Sites (# Sites Outside CARE)	# Total Estimated Sites [3]	Years Monitored in CARE	CARE Sites Revisited
NPS Sensitive Species (continued)	San Rafael phacelia	*Phacelia rafaelensis* [2]	1 (0)	21–80	2016	0
	Welsh's Aster	*Symphyotrichum welshii* [1]	0 (0)	6–80	Not monitored	–
Former NPS Sensitive Species	Alpine Greenthread	*Thelesperma subnudum* var. *alpinum* [1]	2 (14)	6–20	1999–2000	0
	Heil's wild buckwheat	*Eriogonum corymbosum* var. *heilii* [1]	3 (3)	Unknown	2003–2004	0
	Johnson's cryptanth	*Cryptantha johnsonii*	3 (0)	6–20	2004	0
	Low hymenoxys	*Hymenoxys acaulis* var. *nana* [1]	14 (9)	Unknown	2000	0
	Rush Lomatium	*Lomatium junceum* [1]	6 (1)	Unknown	2000, 2002	0
	Woodside wild buckwheat	*Eriogonum tumulosum* [2]	1 (0)	≥17	2004	0

[1] Locally endemic (species whose entire global range is restricted to an area of less than 16,500 km^2 [6,370 mi^2] or 1° of latitude by 2° of longitude) (Fertig 2009).

[2] Regionally endemic (species with a global range of 16,500–250,000 km^2 [6,370–96,526 mi^2], or about the size of Wyoming) (Fertig 2009).

[3] NatureServe (2021).

The rare plants Access database and geodatabase contain information from CARE's and the Interagency Rare Plant Team's monitoring efforts for 17 of the 26 species listed in Table 3.7.2-1. The number of sites was based on the number of unique site names in CARE's Access database. The total number of estimated sites was published by NatureServe (2021), but it's unknown how values were estimated.

At least one species was surveyed in most years since 1997, but not every species or site was monitored each year. From 1997 to about 2004, most efforts were devoted to mapping and assessing the condition of rare plant populations. Of the 426 sites mapped in CARE, only 54 (13%) have been resurveyed and few sites have been surveyed since 2015.

More than half (57%) of the 426 rare plant sites across the 26 target species were mapped in CARE (Figure 3.7.2-1). Overall, just four species listed in Table 3.7.2-1 represent 74% of the 426 locations mapped. These are Last Chance townsendia, Wright fishhook cactus, Winkler cactus, and Maguire daisy. For the six threatened and endangered species and 14 currently sensitive species, 51% and 73% of sites, respectively, were mapped in CARE. For the six formerly sensitive species, 52% of sites were mapped in CARE. The high proportion of sites mapped in CARE is at least partially because of the more intensive efforts in the park than areas outside the park.

Across all species, most rare plant sites in CARE were mapped north of Oak Creek. Mapping and monitoring efforts were greater in the northern portion of the park because one objective of the rare plant surveys was to document disturbance, and this area of the park receives higher visitation than the southern portion of the park (Clark and Clark 1999). NatureServe (2021) published estimates for the number of occurrences (i.e., sites) range-wide for most species listed in Table 3.7.2-1. When comparing NatureServe's estimated number of sites to the number of sites mapped in CARE, it's apparent that CARE serves a critical role in the conservation of many of these species. However, NatureServe data may need updating. For example, there are 99 sites for Winkler cactus in CARE, but NatureServe estimates that there are between one and 20 sites.

For each site visit, surveyors estimated the number of plants (abundance). The plant abundance classes include: no plants, 1–10, 11–50, 51–100, 101–1,000, 1,001–10,000, 10,001–50,000, and > 50,000. In some cases, abundance was not recorded. To compare rare plant abundance in CARE to abundance outside the park, we determined the percentage of sites within CARE versus outside CARE in each abundance class. For sites with multiple visits, we only included the most recent abundance estimate. Only five species occurred in enough sites (i.e., ≥ 15) to compare abundance classes across the park boundary. These are Last Chance townsendia, Wright fishhook cactus, Winkler cactus, Maguire daisy, and pinnate spring-parsley (*Cymopterus beckii*).

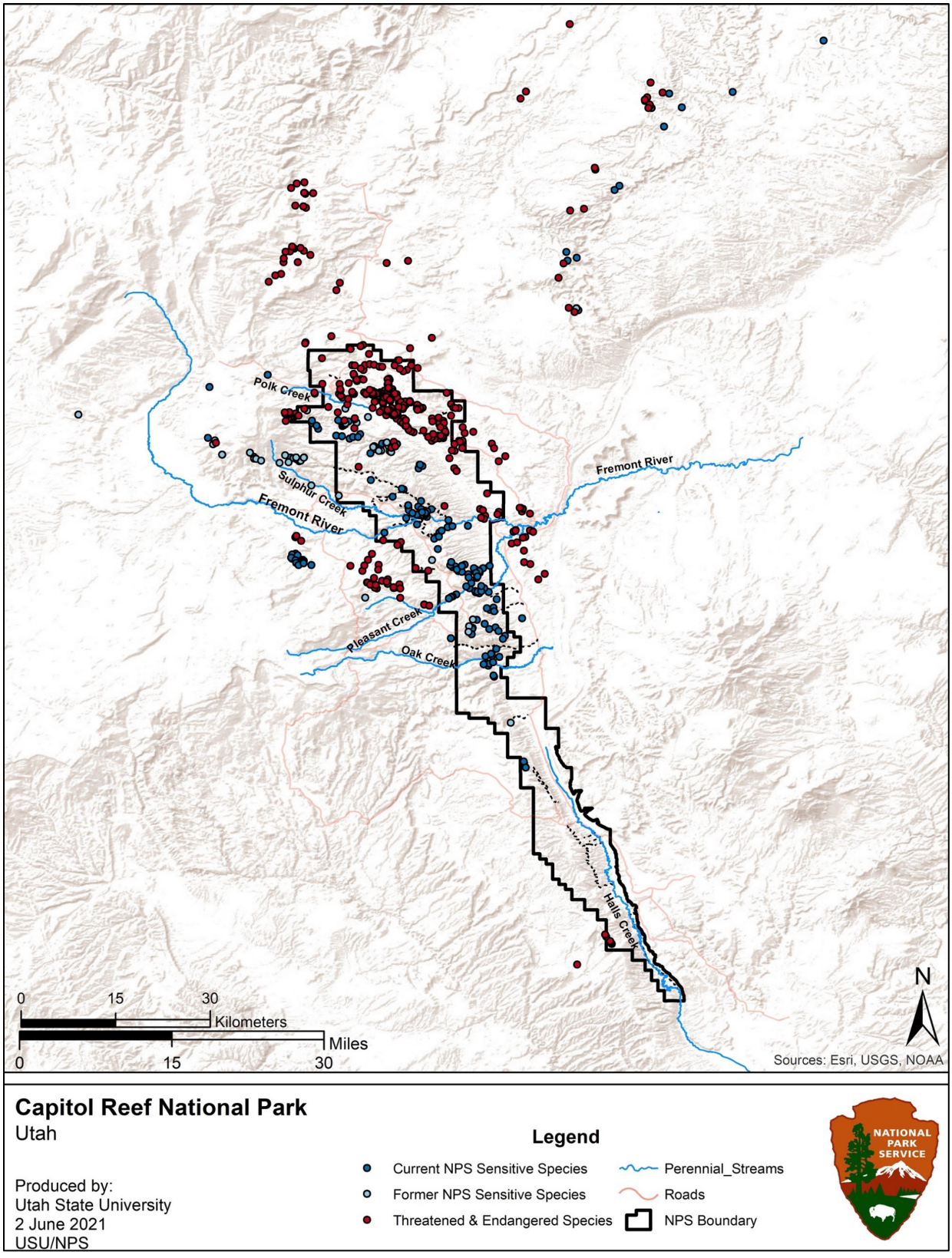


Figure 3.7.2-1. Locations of the six USFWS endangered and threatened plants, 14 NPS sensitive species, and six formerly sensitive NPS species in and around CARE.

For four of the five species (except Wright fishhook cactus) populations were estimated at <100 plants (Figures 3.7.2-2, 3.7.2-3, and 3.7.2-4). Few populations were estimated to be greater than 1,000 plants, and no population was >10,000 plants. Upon follow-up visits to some sites for the three threatened and endangered species, observers reported no plants (Figures 3.7.2-2 and 3.7.2-3). This was more common for Last Chance townsendia and Wright fishhook cactus at sites outside the park, and for Winkler cactus inside the park. Note that the absence of plants does not necessarily indicate that the site is no longer occupied by a given species. Multiple follow-up visits are required to confirm that these sites are unoccupied. For example, some species, like Last Chance townsendia, have long-lived seeds that may be viable for 9–11 years (USFWS, J. Lewinsohn, comments to draft assessment, 1 July 2021). The percentage of sites within each abundance class for Winkler cactus, Maguire daisy, and pinnate spring-parsley were comparable within and outside CARE (Figure 3.7.2-3 and 3.7.2-4). Site abundances of Last Chance townsendia and Wright fishhook cactus tended to be smaller in CARE than outside of CARE, but plant abundance for the latter species were not estimated at a large percentage of sites (i.e., ~30% in CARE and ~60% outside CARE).

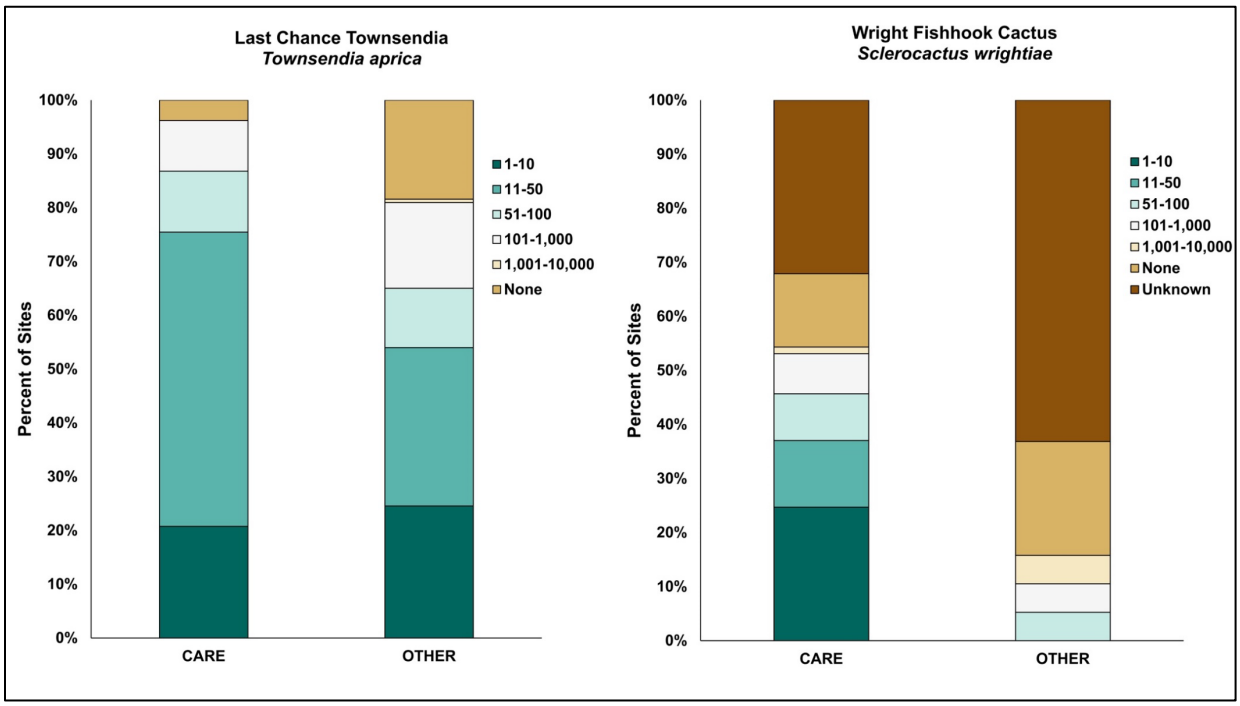


Figure 3.7.2-2. Percentage of sites in each population size category for Last Chance townsendia (left) and Wright fishhook cactus (right) inside and outside of CARE.

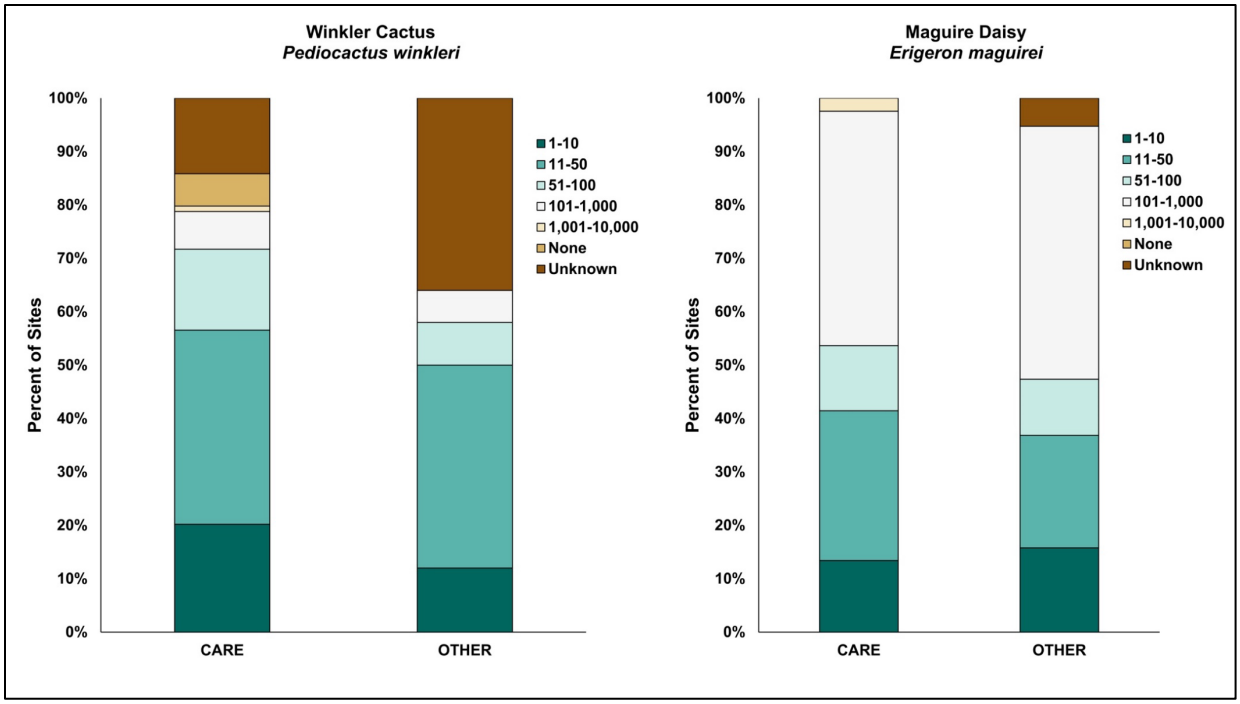


Figure 3.7.2-3. Percentage of sites in each population size category for Winkler cactus (left) and Maguire daisy (right) inside and outside of CARE.

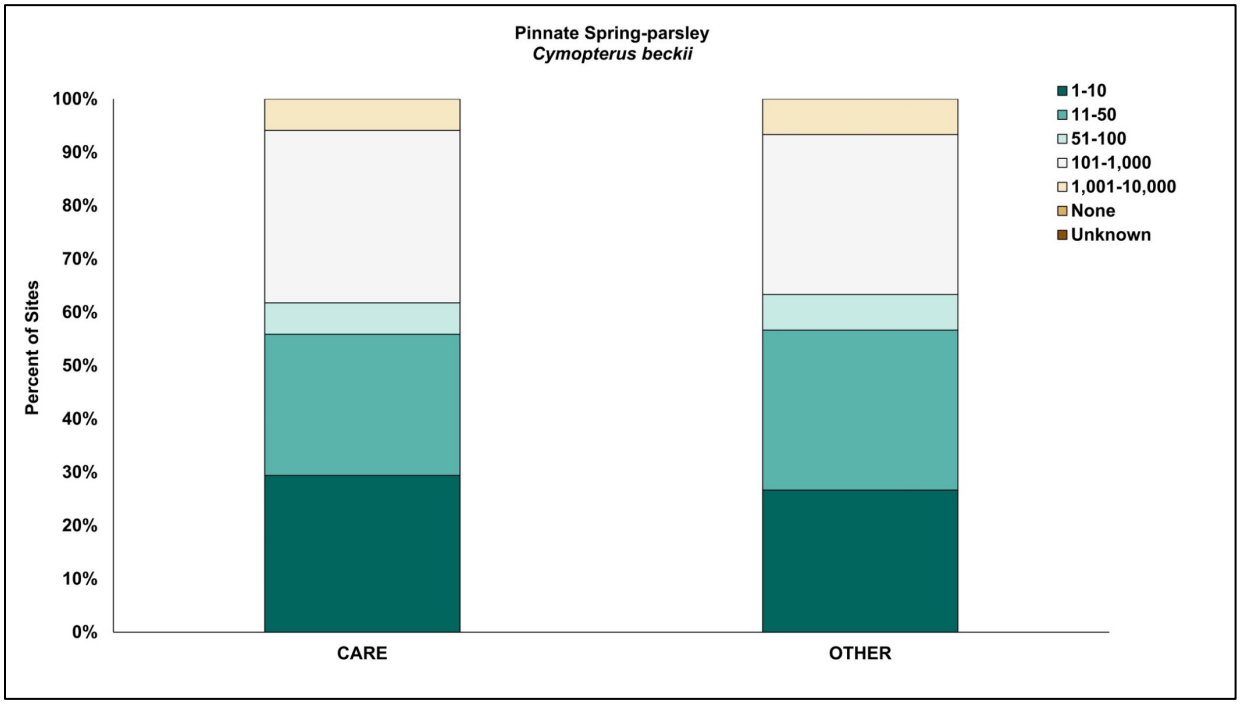


Figure 3.7.2-4. Percentage of sites in each population size category for pinnate spring parsley inside and outside of CARE.

The total number of live Wright fishhook cactus in the park stands conservatively at 3,951 plants as of 2018 (NPS 2018b). Range-wide, this species is estimated at 14,761 plants, which means that CARE supports 27% of the total population. For the Winkler cactus, CARE supports 40–50% of the entire population throughout its range (NPS 2018b). The total population of Winkler cactus is about 5,944 plants, nearly half (46%) of which occur in the park (i.e., 2,758 plants) (NPS 2018b). From 2013 to 2016, mortality of both species in the park exceeded recruitment, which is consistent with declining populations. Protecting cactus plants to increase survival is critically important for stabilizing or reversing this trend (NPS 2018b).

Surveyors rated four measures of plant health at each site: 1) quality (population size, vitality, and vigor), 2) viability (long-term prospects of maintaining the quality rating), 3) habitat condition, and 4) defensibility (possibility of protecting the site from extrinsic human factors). The rating scales for each category were rolled into an overall rating, ranging from excellent to poor. The ratings were only completed for initial site visits (most of which occurred prior to 2004) for 184 sites in CARE and 156 sites outside of CARE. Note that some sites support multiple species of concern.

Figure 3.7.2-5 shows that most sites (~80%) in the park were rated as excellent or good for each of the four measures for an overall rating of excellent or good for 84% of all CARE sites. Outside CARE, only 60% of sites were rated as excellent or good across the four measures. About 36% of the sites outside CARE were rated as marginal or poor. This suggests that sites within the park are in better condition than those outside the park, probably due in part to the lower levels and different types of disturbance.

For most sites with disturbance, native ungulates, livestock grazing and trailing, and human foot traffic along trails or off-trail were most often observed. However, the primary disturbance at half of the sites is unknown (Appendix D, Table D-1). Most of these surveys were completed prior to the completion of the LGTMP in 2018. For those sites in former grazing allotments, disturbance from grazing has been eliminated. Only one grazing allotment (Sandy 3), which is south of Oak Creek, remains active in the park, and several livestock trailing routes continue to be used (NPS 2018b).

The Interagency Rare Plant Team found that elevation, geological formation, and associated plant species were the most useful characteristics in mapping potential habitat for nine rare plant species (Clark and Tait 2007). Aspect and slope were not found to be critical in identifying potential habitat for the nine species, except for the endangered Barneby reed-mustard (*Schoenocrambe barnebyi*), which tends to occur on steep, north-facing slopes in the Moenkopi formation (Clark and Tait 2007). Using Clark and Tait's (2007) approach, we listed the primary geological formations, the elevation range associated with mapped sites, and the primary plant communities in which rare plant sites were mapped in CARE. For those species with no monitoring data in the park, we relied on NatureServe (2021) and USDA and USDOI (2006).

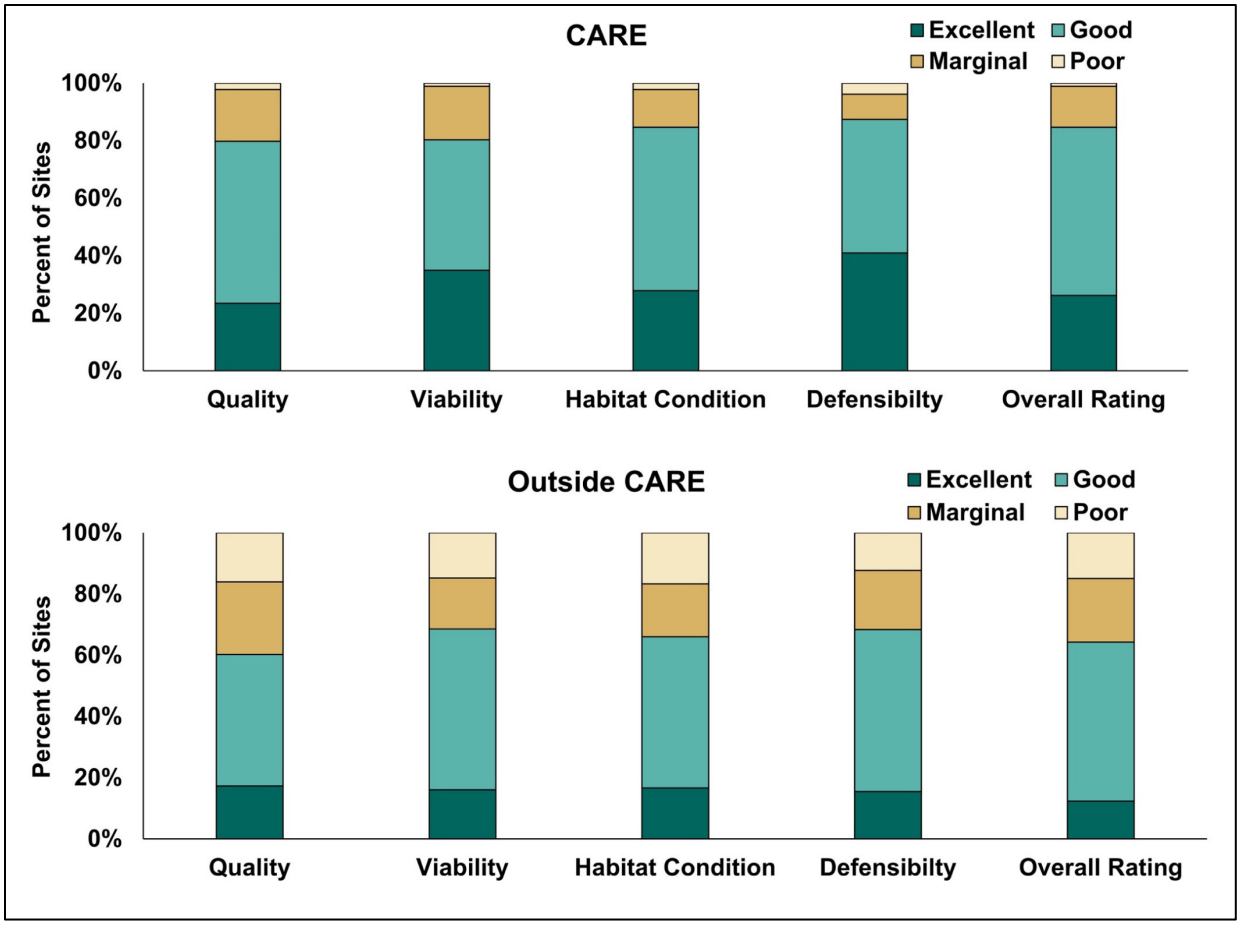


Figure 3.7.2-5. Percentage of sites classified as excellent, good, marginal, and poor inside CARE (top) and outside CARE (bottom).

Many of the rare plants listed in Table D-1 are found in pinyon pine-Utah juniper woodlands, but several species are associated with wetlands or sagebrush shrublands. Rare plants were also mapped in multiple geological formations, including Moenkopi, Navajo Sandstone, Carmel, and Kaiparowits, from elevations as low as 1,065 m (3,494 ft) to 3,400 m (11,155 ft), depending on the species. Elevations within CARE range from 1,180 m (3,880 ft) to 2,730 m (8,960 ft) (Coles et al. 2009). The NPS geology (Graham 2006) and vegetation (Coles et al. 2009) geodatabases, along with a digital elevation model subset to the characteristics summarized in Table D-1 would provide the potential area within which a particular species may occur.

3.7.3. Discussion

The proposed indicators, measures, and reference criteria for assessing the condition of rare plants in CARE are listed in Table 3.7.3-1. These include measures already being collected, such as population size, abundance within sites, overall rating of sites, and the type and degree of disturbance. Developing specific criteria by species will be an important component of a future condition assessment. Given the large number of species included in this analysis, park managers may need to focus on a smaller subset of metrics.

Table 3.7.3-1. Proposed study details for rare plants.

Indicator of Condition	Measure	Reference Criteria for Measure
Population Size and Demography	Number of sites (or populations and metapopulations)	Population and metapopulation dynamics indicate a high likelihood of persistence.
	Population size	The number of individuals is large enough that the probability of extirpation is low.
	Number of plants per life stage	Age structure of population indicates likely persistence.
Overall Rating	Quality rating (size, productivity, vitality, vigor)	Excellent to Good
	Viability rating (long-term prospects of quality rating)	Excellent to Good
	Habitat Condition Rating	Excellent to Good
	Defensibility rating (possibility of protecting the site from extrinsic human factors)	Excellent to Good
Disturbance	Type and degree	No direct impacts observed; site is at low risk for disturbance. Observed disturbances are natural and within the range of natural variation for the ecosystem.

There are three key data gaps for CARE's rare plants. The first is the lack of a monitoring strategy given the high number of species of concern and large number of sites in CARE. With the available data, we could not determine the condition of rare plants in the park because of the absence of systematic monitoring. Defining a suite of management questions will help refine a future study approach. The database also contains several sites with different spellings or names that make it unclear whether they are the same or different sites. The second data gap is the lack of specificity for the four criteria used to rate site quality. These four criteria were all assigned a rating in the rare plants database, but it is not clear how they were derived. These criteria, however, may be useful in conducting rapid assessments for a higher number of sites if the criteria were better defined and developed. This could then be supplemented with more intensive surveys for a subset of sites. The third data gap is to change the focus of the rare plants database to species rather than sites. While some sites contain more than one species of concern, this approach may be less informative than a species-specific monitoring strategy. The rationale of the site-specific approach was because surveys were tied to monitoring the effects of grazing. Now that grazing occurs only in a portion of the Sandy 3 allotment, expanding surveys to other areas of the park is needed to fill this data gap.

In CARE's rare plants Access database, surveyors suggested several monitoring strategies based on the vulnerability of each site to disturbance, most of which fell into six main monitoring classes: annual, biennial, every 3–5 years, periodic, regular, and event-specific monitoring (Figure 3.7.3-1). The periodic and regular monitoring categories are not well defined and could be integrated into one of the three more specific monitoring categories (i.e., annual, biennial, every 3–5 years), especially

considering that 72% of all sites were classified as periodic or regular monitoring sites. However, frequent monitoring may damage sites and create social trails that encourage visitors to wander from established paths (The Arboretum at Flagstaff, S. Murray, research botanist, e-mail message to D. Witwicki, 22 June 2021). Although a strategy for monitoring sites is useful, a monitoring strategy by species would also be helpful in developing a long-term monitoring plan. An additional consideration is the development of a seedbank for rare species, particularly for those in decline (The Arboretum at Flagstaff, S. Murray, research botanist, e-mail message to D. Witwicki, 22 June 2021).

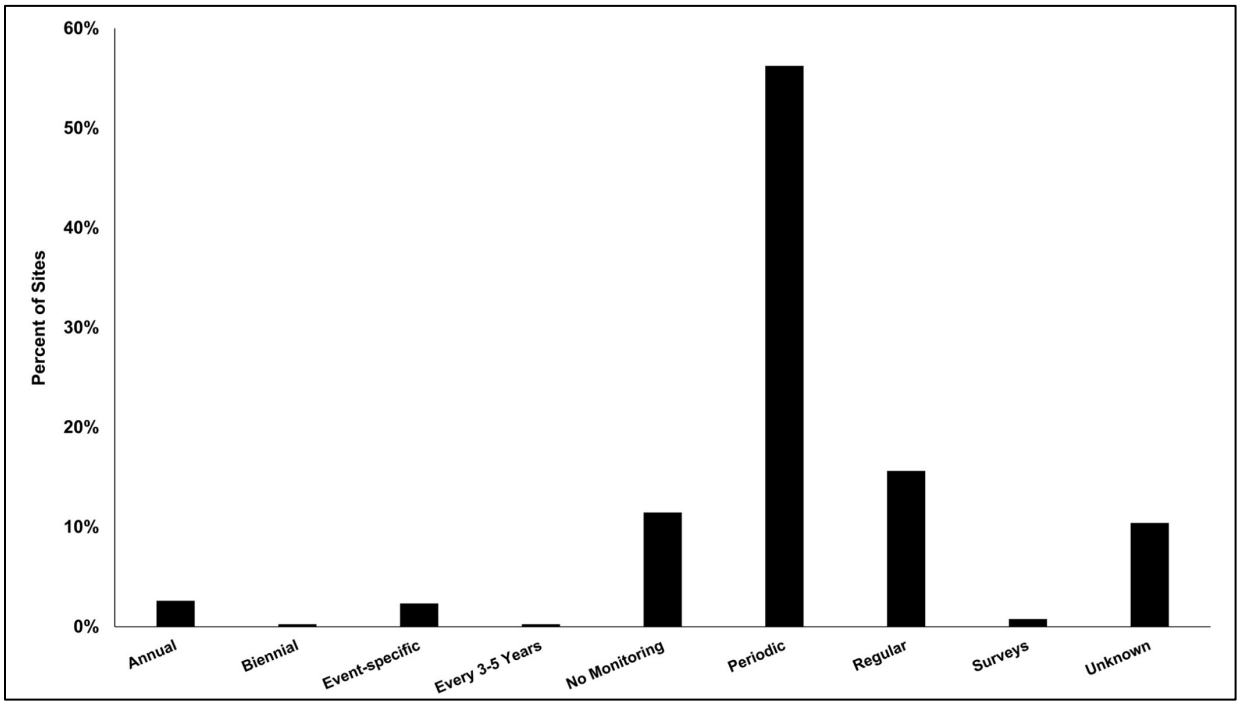


Figure 3.7.3-1. Percentage of sites in each of nine potential monitoring classes.

Event-specific monitoring is suggested for those sites in planned management areas or in areas requiring changes in management to protect rare plants (e.g., trail reroutes). About 11% of the sites do not require monitoring because they are naturally protected from disturbance or because monitoring itself would cause disturbance. Less than 1% of sites require more thorough surveys, and no monitoring strategy was suggested for the remaining 10% of sites. In addition to site-specific monitoring strategies, it's important to note that many species only bloom during years with adequate rainfall (Clark and Groebner 2001). Although plants may only bloom in years with average or above average precipitation, understanding how a species responds during dry, average, and wet years is essential for understanding its life history and ecology, and guiding management under climate change (Manzanita Botanical Consulting, J. H. Hornbeck, botanist, comments to draft assessment, 1 July 2021). Lastly, sites classified as marginal or poor should be given priority for monitoring; however, pairing poor and marginal sites with control or reference sites would help managers better understand how plants respond in undisturbed versus disturbed sites (Manzanita Botanical Consulting, J. H. Hornbeck, botanist, comments to draft assessment, 1 July 2021). This type of

monitoring strategy could be coordinated with the BLM and USFS to gain a better understanding of rare plants over a larger area.

As previously mentioned, a portion of CARE's rare plants is naturally protected because some populations are difficult to reach, but several sites also occur in high-use areas (e.g., the Fruita District, along hiking trails and roads, cattle trailing routes, and in the park's remaining grazing allotment). Wright fishhook cactus and Winkler cactus occur along three potential trailing routes in the park (Grey Bench-Cathedral Valley, Hartnet, and Lower South Desert) (NPS 2018b). Approximately 10% of the park's total known populations for both species occur along these routes (NPS 2018b). Those species that are short and small tend to be most difficult to see and are most likely to be trampled (e.g., Winkler cactus). Illegal collection is also an occasional problem in the park. In the rare plants database, one surveyor noted that several cactus plants had been uprooted at one site for apparent collection.

Native ungulates, like desert bighorn sheep and elk (*Cervus elaphus*), also trample rare plants in some locations, particularly in the remote Cathedral District of the park (NPS 2018b). Native black-tailed jackrabbits (*Lepus californicus*) are also a threat to rare plants, particularly to the two threatened and endangered cactuses, since they graze on the flowers (NPS 2018b). Rare cactuses are also subject to defoliation from cyclic insects. The cactus borer beetle (*Moneilema semipunctatum*) and *Rhagea* spp. moth larvae have caused substantial mortality at some of the cactus sites (NPS 2018b).

Competition from invasive plant species is also a stressor to rare plants. Over 120 non-native plant species have been reported for the park, which represents about 14% of CARE's total plant species (Fertig 2009). Twelve non-native species are actively controlled because they pose the greatest and most immediate threat to native plant communities (NPS 2020d). These include tree-of-heaven, Russian knapweed (*Centaurea repens*), bull thistle, five-stamen tamarisk (*Tamarix chinensis*), and wooly mullein (*Verbascum thapsus*) (NPS 2020d).

Climate change also plays a role in the survival and reproduction of rare plants, and it can interact with the abovementioned stressors to lower the ability of plants to adapt to disturbance, invasive plants, and insects. The role of pollinators is also crucial to the persistence of rare plants, but how pollinators are responding or will respond to climate change is not well understood. As already mentioned, years with higher rainfall result in higher flowering rates for many rare plant species. Survival of Winkler cactus is correlated with higher rainfall, while drought contributes to adult mortality, low recruitment rates, and population declines (NPS 2018b). While warmer minimum spring temperatures may cause higher recruitment for Winkler cactus, there may be a threshold above which recruitment declines, either due to heat stress, drought, or both. Furthermore, many of the species considered in this gap analysis are local or regional endemics with limited ranges. The ability of endemic species to shift their range in response to climate change is more limited than for generalist species (Krause et al. 2015). Still et al. (2015) found that Winkler cactus is extremely vulnerable to climate change, with no overlap between current and predicted future habitat. Some species, like Winkler cactus, can contract belowground during unfavorable climate conditions, which may help the species adapt to a changing climate.

CARE's protected area status and high concentration of rare and endemic species make the park critical to the conservation of rare plant species. For example, Harrison's milkvetch (*Astragalus harrisonii*) only occurs in CARE (USDA and USDOI 2006), and half of the total range of Winkler cactus occurs in the park (NPS 2018b). Additionally, the Interagency Rare Plant Team's monitoring area includes lands managed by the NPS, BLM, USFS, Utah, and private landowners (Clark and Tait 2007). Of these land management units, the NPS has the highest level of protection.

3.8. Songbirds (Condition Assessment)

3.8.1. Background & Importance

Riparian habitat is a rare and threatened community type in Utah and elsewhere in the western U.S. (NAS 2008). The Fremont River riparian corridor in CARE was designated a National Audubon Society (NAS) Important Bird Area because the plant community along the river provides critical habitat for migrating and breeding birds, including several Utah Partners in Flight (PIF) priority species (Parrish et al. 2002). Monitoring birds is important because they are good indicators of ecological change and ecosystem health, and because they play an important role in food webs and energy flow (Daw et al. 2020).

Although national parks are generally strongholds for wildlife and plants, climate change has already caused range shifts and changes in behavior for some bird species, such as earlier nesting in spring and later migration in autumn (Carey 2009; Wu et al. 2018). In addition to climate change, birds face numerous threats throughout their ranges, including loss of habitat, contaminants and pollution, reflective buildings and wind farms, bright city lights that interfere with nocturnal migration, and outdoor cats (Loss et al. 2015). These and other threats have contributed to a nationwide decline of nearly 30% of total individuals (an estimated three billion birds) since the 1970s (Rosenberg et al. 2019).



The broad-tailed hummingbird is common in CARE's riparian habitat. Image Credit: © R. SHANTZ.

3.8.2. Study Framework

We used species richness and abundance or density to evaluate community composition (Table 3.8.2-1). The condition rating statements (Appendix B, Table B-5) were based on the NOAA Marine Sanctuary criteria for living resources (NOAA 2018). Songbirds at CARE have been monitored through multiple efforts, and Figure 3.8.2-1 shows the locations of the bird survey sites described in this assessment.

Table 3.8.2-1. Study details for the songbirds condition assessment.

Indicator of Condition	Measure	Reference Criteria for Measure
Community Composition	Richness	No loss of native species and/or species expected to occur in a particular habitat are present.
	Abundance or Density	No declines in obligate or dependent species or species of conservation concern in pinyon-juniper, riparian, and grassland/shrubland habitats.

In 1987, two (Notom and Desert View) USGS BBS routes, primarily in grasslands/shrublands, were established in and around the park. These road-based surveys consist of three-minute counts at 50 locations spaced approximately 0.8 km (0.5 mi) apart (Pardieck et al. 2020). The Desert View route was surveyed in 23 of the last 33 years, while the Notom route was surveyed in 25 of the last 33 years.

From 1992 to 2011, the Utah Division of Wildlife Resources (UDWR), Utah PIF, and other partners surveyed 10, point count locations along the Fremont River as part of a state-wide effort to better understand the status and trends of riparian songbirds throughout the state (Pope et al. 2015). A companion Monitoring Avian Productivity and Survivorship (MAPS) banding station was operated at this location (38°25'N, −111°25'W) from 1996 to 2007 (IBP 2019) and was within the area of the point counts. Also, from 2005 to 2019 (except 2016), the NPS NCPN conducted annual point count surveys along two riparian (Pleasant and Halls creeks) and two pinyon-juniper transects in the park (Roberts et al. 2020).

In addition, S. Borthwick (CARE biologist) has led an annual (2010–present) public bird walk (NPS, S. Borthwick, biologist, Excel spreadsheet, 2 February 2021) as part of Environment for the Americas' International Migratory Bird Day (IMBD) (Wheeler and Bonfield 2005). The event is on the second Saturday in May. It begins near the confluence of Sulphur Creek and the Fremont River and continues along the Fremont River trail, which winds along the river past the Gifford House, the campgrounds, orchards, and Hattie's Field (NPS, S. Borthwick, CARE biologist, e-mail message, 17 February 2021). The IMBD walk serves primarily as a tool to educate the public about the importance of birds and the threats they face (Wheeler and Bonfield 2005).

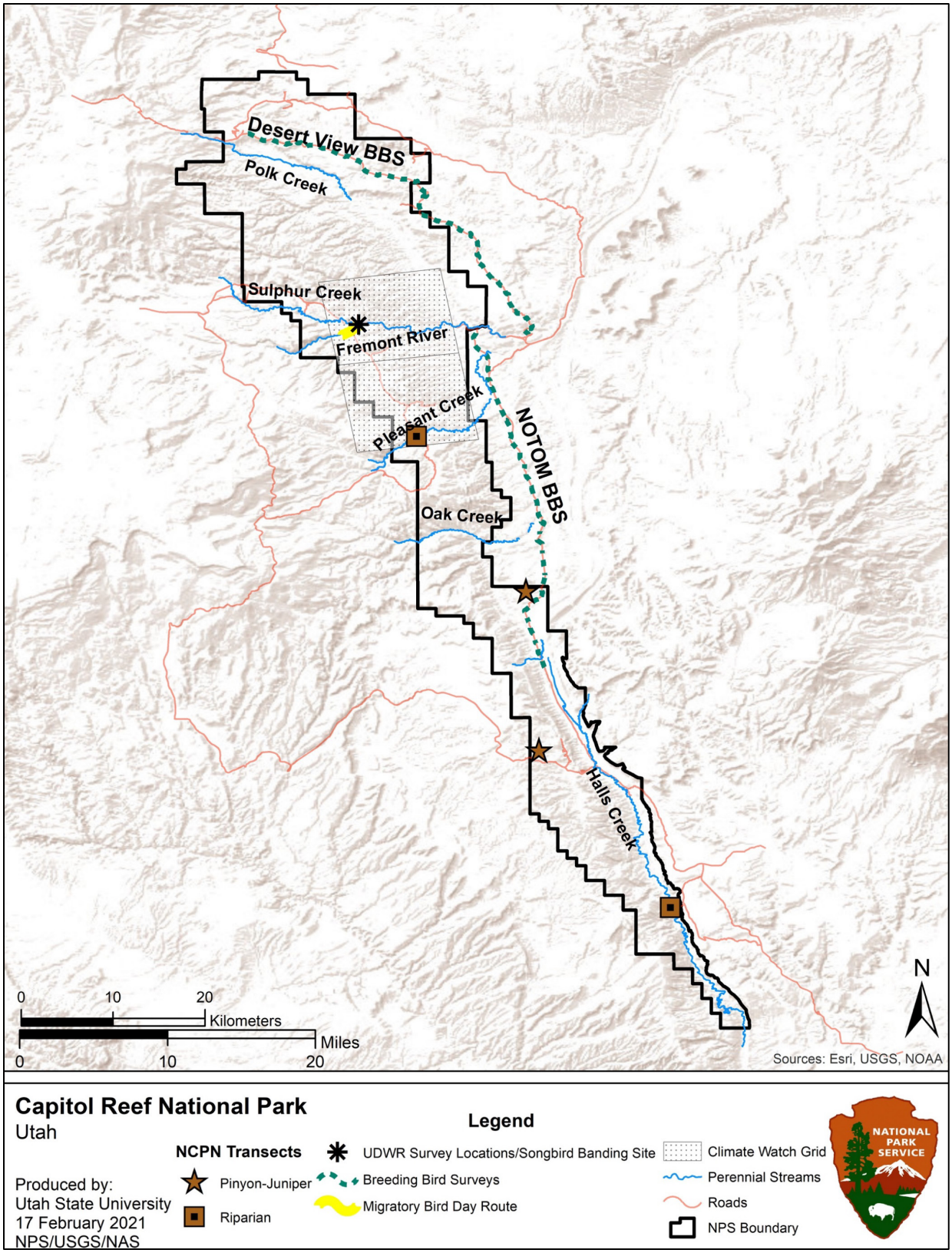


Figure 3.8.2-1. Survey locations for songbird studies in CARE.

Lastly, there are 12, point count stations in each of two NAS Climate Watch count grid squares (10 x 10 km [6.2 x 6.2 mi]) in CARE (NPS, S. Borthwick, biologist, Excel spreadsheet, 3 February 2021). Climate Watch surveys were established by NAS in 2016 to validate (ground-truth) models for how select species are predicted to respond to climate change (Wu et al. 2018; Saunders et al. 2020). Target species include bluebirds, nuthatches, goldfinches, towhees, and buntings. Surveys are conducted on one day in mid-winter (15 January–15 February) and one day in spring/summer (15 May–15 June). Although there is also a NAS Christmas Bird Count circle that partially overlaps the northern end of the park, those data were not parsed by area, so we could not include them in this assessment. While these monitoring efforts are valuable and can be informative to bird status at CARE, it is important to note that none of these were established specifically to provide inference about conditions at the park level.

3.8.3. Data & Methods

We developed a list of sensitive songbirds, woodpeckers, and hummingbirds that occur in CARE based on the Utah Wildlife Action Plan (UDWR 2015) and Utah PIF priority species (Parrish et al. 2002), the NAS Climate Watch species (Wu et al. 2018; Saunders et al. 2020), and the NAS/NPS highly climate-sensitive species (Schuurman and Wu 2018). We summarized these species by their relative abundance, residency status, and habitat associations in CARE using CARE's checklist of birds (NPS 2015b). We also included their projected climate response (by 2050) as reported in Schuurman and Wu (2018). This list, as well as the most common obligate and dependent species in riparian, pinyon-juniper, and grassland/shrubland, served as the focus for this assessment, although not all species of conservation concern were adequately surveyed.

Rich (2002) defines riparian obligate species as those that "place >90% of their nests in riparian vegetation or for which 90% of their abundance occurs in riparian vegetation during the breeding season." Riparian-dependent species are those that "place 60–90% of their nests in riparian vegetation or for which 60–90% of their abundance occurs in riparian vegetation during the breeding season" (Rich 2002). Gillihan (2006) and Paulin et al. (2001) consider pinyon-juniper obligate bird species as those that are only detected in pinyon-juniper forests and semi-obligate species as those that are only detected in one other forest type.

For the measures of richness and abundance or density, we relied on data collected by UDWR, NCPN, and park staff monitoring birds along the BBS routes. For both the NCPN and UDWR data sets, we restricted our summaries to include only passerines (except for swallows), hummingbirds, and woodpeckers. We also eliminated flyovers and birds recorded more than 125 m (410 ft) from the observer to reduce the probability of double-counting birds (counts were spaced at least 250 m (820 ft) apart in NCPN surveys and at least 150 m (492 ft) apart in UDWR surveys). Using these data, we reported mean annual richness and abundance, but did not calculate trends in richness and abundance because data for the park represent just one or two sampling sites that are part of larger studies at either the state (UDWR) or the NCPN level. Annual abundance was calculated as the average number of individuals observed per point count station averaged over all point counts along the respective transect. Data were not corrected for detectability.

The NCPN surveys birds in 11 of the 16 national parks included in the network that are on the Colorado Plateau, and the inference of that monitoring program is to pinyon-juniper, sagebrush (not sampled in CARE), and riparian habitat across all 11 parks. Similarly, the level of inference for UDWR riparian data was also at the state level. Therefore, we reported published results on trends in density for select species at the NCPN level (Roberts et al. 2020) and the state level (Pope et al. 2015). For these two studies, we reported 1) trends for the most common obligate and dependent species in riparian and pinyon-juniper study sites and 2) trends for species of concern based on the three lists described above. Although we could not determine trends for species within the park, results published by Pope et al. (2015) and Roberts et al. (2020) serve as a proxy for conditions in the park.

Using the BBS data, we calculated trends in overall richness and abundance, and abundance for select grassland/shrubland species, with at least 80 detections for all years. For a list of obligate and dependent grassland/shrubland species, we relied on Paige and Ritter (1999). Using trends published on the USGS BBS website (Pardieck et al. 2020), we compared statewide trends to trends in CARE. The remaining data (i.e., IMBD, Climate Watch, banding data) were summarized by total richness, relative abundance of the most reported species, and richness of obligate and dependent species for the respective habitat type in which the survey occurred.

3.8.4. Results & Discussion

According to NPSpecies (2021), there are 234 bird species confirmed for CARE (seven of which are non-native). There are an additional eight species considered "probably present" and six species listed as "unconfirmed," all of which are native. Four of the seven non-native species include European starling (*Sturnus vulgaris*), house sparrow (*Passer domesticus*), Rock pigeon (*Columba livia*), and Eurasian collared-dove (*Streptopelia decaocto*). The remaining three non-native species are game birds: (chukar [*Alectoris chukar*], ring-necked pheasant [*Phasianus colchicus*], and wild turkey [*Meleagris gallopavo, possibly M. gallopavo merriami*]).

There are 20 species in the park that are listed as conservation priorities (Parrish et al. 2002; UDWR 2015), climate watch species (Wu et al. 2018; Saunders et al. 2020), and/or climate-sensitive species (Schuurman and Wu 2018) (Table 3.8.4-1). Of the 20 species (hereafter referred to as species of conservation concern), 17 breed in CARE, while the remaining three species migrate through during spring and autumn. Several of the breeding species are year-round residents. Most species listed in Table 3.8.4-1 occur in more than one habitat type, with riparian, pinyon-juniper woodlands, and the Fruita developed area being the most common associations.

Table 3.8.4-1. List of NAS Climate Watch, Utah Partners in Flight, and NPS/NAS highly climate-sensitive songbirds, woodpeckers, and hummingbirds that occur in CARE.

Common Name	Relative Abundance	Residency Status	Predicted Climate Response by 2050 (summer/winter)	Habitat Code [5]
American goldfinch [1]	Uncommon	Summer	Potential extirpation/Not found [4]	R, F
Black rosy-finch [2]	Uncommon	Migratory/Winter	Not assessed	S, F
Black-billed magpie [3]	Uncommon	Resident	Potential extirpation/ Not found [4]	P, R
Black-throated gray warbler [2]	Common	Summer	Stable/ Not found [4]	P, R, F
Brewer's sparrow [2]	Common	Summer	Worsening/Potential colonization	S, R
Broad-tailed hummingbird [2]	Common	Summer	Stable/Not found [4]	H, P, S, R, F
Clark's nutcracker [3]	Uncommon	Resident	Potential extirpation/Worsening	H, P
Gray flycatcher [2]	Uncommon	Summer	Stable/Potential colonization	P, S
Gray vireo [2]	Uncommon	Summer	Not assessed	P
Lesser goldfinch [1]	Uncommon	Summer	Improving/Potential colonization	R, F
Lewis's woodpecker [2]	Rare	Migratory	Not assessed	R, F
Lucy's warbler [2]	Occasional	Breeder [6]	Improving/Not found [4]	R, F
Mountain bluebird [1]	Uncommon	Resident	Stable/Improving	P, S, R, F
Red-naped sapsucker [3]	Uncommon	Resident	Worsening/Not found [4]	R, F
Sagebrush sparrow [2,3]	Uncommon	Summer	Worsening/Not found [4]	S
Spotted towhee [1]	Common	Resident (rare in winter)	Stable/Not modeled	R, F
Virginia's warbler [2]	Common	Summer	Not assessed	H, P, R, F

[1] NAS Climate Watch.

[2] Utah Partners in Flight.

[3] NPS/NAS highly climate-sensitive.

[4] Predicted Climate Response is that species is not found or found only occasionally and is not projected to colonize by 2050. Predicted summer and winter responses are separated by a slash.

[5] Habitat Codes are R = riparian, F = Fruita developed area, S = shrub/shrub grassland, P = pinyon-juniper forest, H = high elevation forest.

[6] Listed as an occasional migrant in CARE's checklist (NPS 2015b), but a nest was discovered in 2018 along Halls Creek (University of Delaware, S. Roberts, research associate, comment to draft assessment, 17 August 2021).

Table 3.8.4-1 (continued). List of NAS Climate Watch, Utah Partners in Flight, and NPS/NAS highly climate-sensitive songbirds, woodpeckers, and hummingbirds that occur in CARE.

Common Name	Relative Abundance	Residency Status	Predicted Climate Response by 2050 (summer/winter)	Habitat Code [5]
Western bluebird [1]	Rare	Summer	Stable/Potential colonization	H, P
Western wood-pewee [3]	Common	Summer	Worsening/Not found [4]	R, H, P, F
White-breasted nuthatch [1]	Uncommon	Resident	Stable/Not found [4]	H, P, R, F

[1] NAS Climate Watch.

[2] Utah Partners in Flight.

[3] NPS/NAS highly climate-sensitive.

[4] Predicted Climate Response is that species is not found or found only occasionally and is not projected to colonize by 2050. Predicted summer and winter responses are separated by a slash.

[5] Habitat Codes are R = riparian, F = Fruita developed area, S = shrub/shrub grassland, P = pinyon-juniper forest, H = high elevation forest.

[6] Listed as an occasional migrant in CARE's checklist (NPS 2015b), but a nest was discovered in 2018 along Halls Creek (University of Delaware, S. Roberts, research associate, comment to draft assessment, 17 August 2021).

According to Schuurman and Wu (2018), seven of the 16 species with a predicted climate response for summer are expected to decline or become extirpated in the park during the breeding season, including residents of Clark's nutcracker (*Nucifraga columbiana*), red-naped sapsucker (*Sphyrapicus nuchalis*), black-billed magpie (*Pica hudsonia*), and sagebrush sparrow (*Artemisiospiza nevadensis*). During winter, several species are expected to increase or colonize the park, including Brewer's sparrow (*Spizella breweri*), western bluebird (*Sialia mexicana*), and mountain bluebird (*Sialia currucoides*). Some species, like the broad-tailed hummingbird (*Selasphorus platycercus*), are not expected to change. It's important to note that these projections are based on their likely response to changes in climate and do not account for potential changes in habitat, which could be significant (Schuurman and Wu 2018).

At the Fremont River site, observers reported 83 species over the 20 years of surveys (86 including non-target species). The most common species reported were American robin (*Turdus migratorius*), yellow warbler (*Setophaga petechia*), yellow-breasted chat (*Icteria virens*), Bullock's oriole (*Icterus bullockii*), and brown-headed cowbird (*Molothrus ater*), which were also some of the most common species reported statewide (Pope et al. 2015). Of the 83 species observed in the park, 26 (31%) are obligate riparian or riparian-dependent species. The most common riparian obligate and riparian-dependent species included black-headed grosbeak (*Pheucticus melanocephalus*), warbling vireo (*Vireo gilvus*), yellow warbler, and western wood-pewee (*Contopus sordidulus*) (Table 3.8.4-2).

Average richness and abundance at the Fremont River site appeared to increase slightly, as did the abundances for several common riparian species, including Bullock's oriole, western wood-pewee, yellow warbler, and yellow-breasted chat (Figure 3.8.4-1). Across riparian habitat in Utah, these four species exhibited a significant positive trend in density (Table 3.8.4-2). Six of the species listed in Table 3.8.4-2 are also species of concern, including American goldfinch (*Spinus tristis*) and spotted towhee (*Pipilo maculatus*). Statewide, American goldfinch significantly declined, while spotted towhee was stable to increasing. Statewide trends were unavailable for the four remaining species due to low abundance or because the results were inconclusive (Pope et al. 2015). House wren was the only other species listed in Table 3.8.4-2 as declining statewide.

From 1996 to 2007, 57 species were captured at the Fremont River banding station, and there were 772 captures during the 12 years of banding. A total of 604 individuals were banded (hummingbirds and unidentified species were not banded), and 103 of them were captured more than once (i.e., 17% total recapture rate over all years). However, there were no reported recaptures from 1996 to 2001, which is unlikely. It's possible that recaptured birds were not processed during these years, but it's more likely that recapture data were not included in the database sent to Utah State University. The data were received in two different files: one with data from 1996 to 2001 from the USGS, and the other with data from 2002 to 2007 from Institute for Bird Populations via USGS.

Table 3.8.4-2. Relative abundance, density (birds/ha) with 95% confidence interval, and statewide trends for common riparian species and species of concern observed at the Fremont River site from 1992 to 2011 (as reported in Pope et al. (2015)). Riparian affiliation was obtained from Rich (2002). Birds not listed in Rich (2002) but common in riparian habitat are referred to as "associated.".

Species	Relative Abundance in CARE	Statewide Density (birds/ha)	Statewide Trend	Riparian Affiliation
American goldfinch [1]	Uncommon	0.48 (0.46, 0.50)	Declining	Dependent
Black-headed grosbeak	Common	0.18 (0.17, 0.18)	Increasing	Dependent
Broad-tailed hummingbird [2]	Common	–	Not assessed	Associated
Bullock's oriole	Common	0.29 (0.27, 0.30)	Increasing	Dependent
House wren	Common	0.34 (0.31, 0.36)	Declining	Dependent
Lazuli bunting	Common	0.50 (0.46, 0.54)	Stable to Increasing	Dependent
Lesser goldfinch [1]	Common	0.32 (0.30, 0.34)	Inconclusive	Dependent
Lucy's warbler [2]	Rare	0.19 (0.18, 0.20)	Not assessed	Dependent
Song sparrow	Common	0.67 (0.64, 0.70)	Stable	Obligate
Spotted towhee [1]	Common	1.64 (1.58, 1.70)	Stable to Increasing	Associated
Virginia's warbler [2]	Common	0.31 (0.29, 0.35)	Not assessed	Associated
Warbling vireo	Common	1.64 (1.58, 1.70)	Stable to Increasing	Dependent
Western wood-pewee [3]	Common	0.24 (0.23, 0.25)	Inconclusive	Dependent
Yellow-breasted chat	Common	0.18 (0.17, 0.18)	Increasing	Obligate
Yellow warbler	Abundant	4.45 (4.31, 4.59)	Increasing	Obligate

[1] NAS Climate Watch species.

[2] Partners in Flight priority species.

[3] NPS/NAS highly climate-sensitive species.

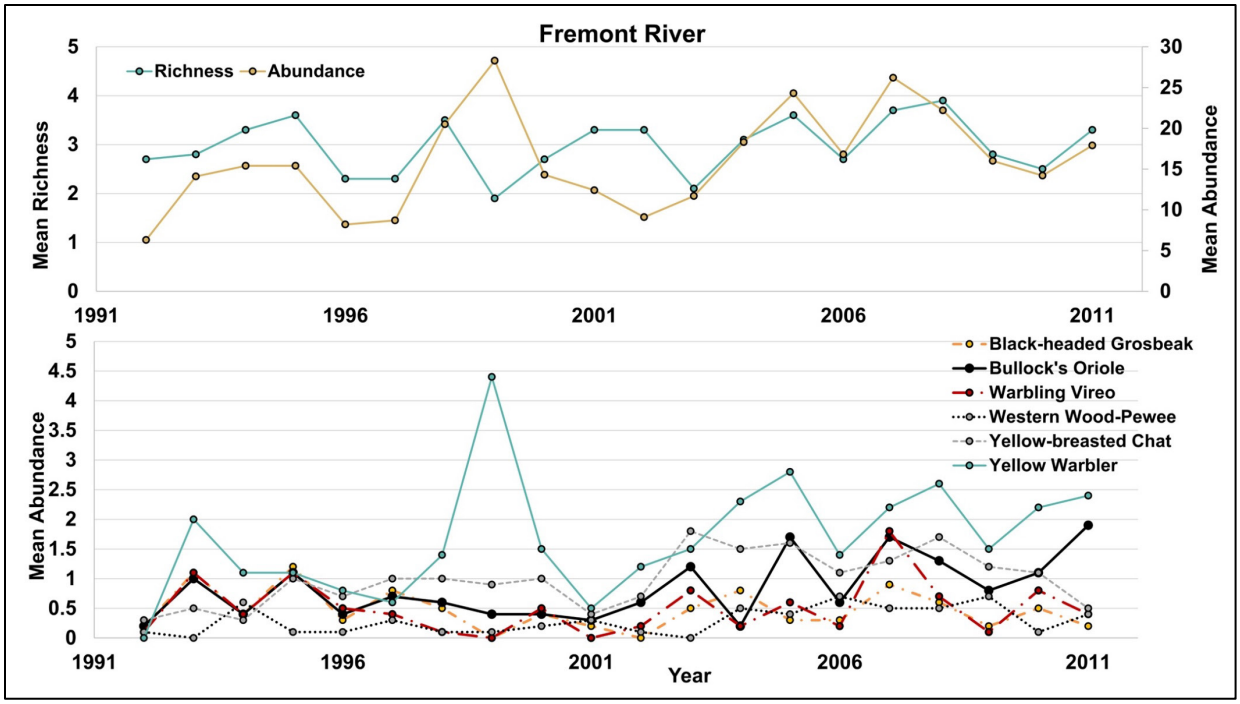


Figure 3.8.4-1. Mean annual richness and abundance (top) and mean annual abundance for the six most common obligate riparian or riparian-dependent species observed at the UDWR's Fremont River site from 1992 to 2011 (bottom).

The recapture rate across all banded birds from 2002 to 2007 averaged 31%. The three most common species captured were yellow-breasted chat (13% of all captures), American robin (12% of all captures), and black-headed grosbeak (7% of all captures). Fifteen species comprised 80% of total captures, and just under half (48%) of all captures were comprised of riparian obligate and riparian-dependent species. Not surprisingly, yellow-breasted chat was the most recaptured species, followed by the black-headed grosbeak and yellow warbler.

Since 2010, 70 species have been observed on the annual IMBD walk. On average, 29 species (18–36) were observed in a given year, five of which have been observed in all 10 years. These were the American robin, black-headed grosbeak, brown-headed cowbird, Bullock's oriole, and yellow warbler, all of which (except for brown-headed cowbird) are riparian specialists. Of the 70 species observed, 54 were neotropical migrants. Many neotropical migrants were observed in only one year (35%), but 43% of neotropical migrants were observed in five or more years.

Between the two NCPN riparian monitoring sites, 69 bird species were observed from 2005 to 2019 (61 at Pleasant Creek and 51 at Halls Creek). In a 1977 survey of birds (and other fauna) along Halls Creek, Lindahl (1977) reported 71 species of birds (43 of the species are the focus of this assessment). Annual richness averaged 6.01 birds/point count at Pleasant Creek and 5.49 birds/point count at Halls Creek. Mean annual abundance was similar at Pleasant Creek (7.75) and Halls Creek (7.60). A paired t-test indicated that these slight differences were not significant for richness ($t(13) = -1.81$, $p = 0.09$) or abundance ($t(13) = -0.50$, $p = 0.62$). There also appears to be a slight downward

trend in richness and abundance, but we did not evaluate for trends. Data were combined for Pleasant and Halls creek and are shown in Figure 3.8.4-2.

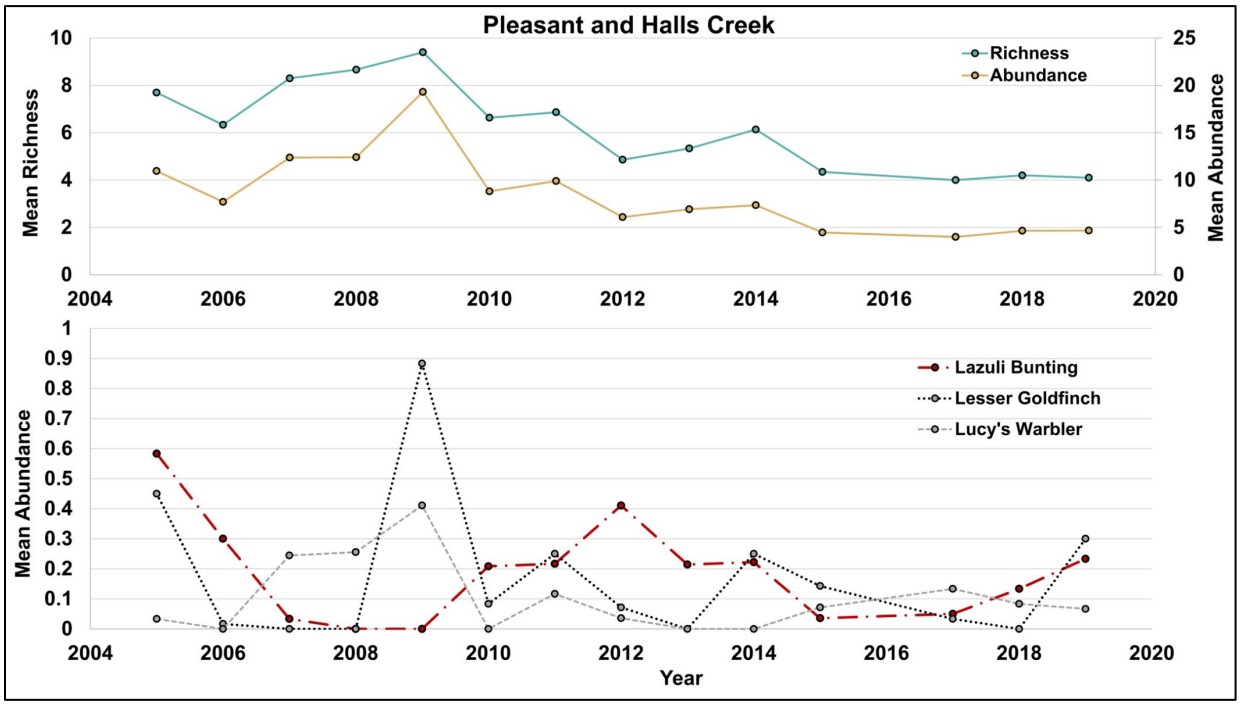


Figure 3.8.4-2. Mean annual richness and abundance (top) and mean annual abundance for the three most common obligate riparian or riparian-dependent species (bottom) at NCPN riparian monitoring transects from 2005 to 2019.

The most common species across the NCPN transects were house finch (*Haemorhous mexicanus*), black-throated sparrow (*Amphispiza bilineata*), ash-throated flycatcher (*Myarchus cinerascens*), spotted towhee, blue-gray gnatcatcher (*Polioptila caerulea*), rock wren (*Salpinctes obsoletus*), mourning dove (*Zenaida macroura*), and Say's phoebe (*Sayornis saya*). Although some of these birds are associated with riparian areas (e.g., spotted towhee), none are riparian obligate or riparian-dependent species, and some of them are more commonly associated with grasslands, including Say's phoebe and black-throated sparrow (Birds of the World 2020). This is probably a reflection of the narrow and confined nature of the riparian area along these creeks (Coles et al. 2009) rather than a reflection of habitat quality.

A 2019 rapid condition assessment of riparian function along Pleasant Creek indicated that plant community composition and structure was in good condition with a well-developed Fremont cottonwood canopy and willow species shrub layer (Borthwick et al. 2019b,c). Although invasive tamarisk species were present, neither species was dominant (Borthwick et al. 2019b,c).

Of the 69 species observed at the NCPN study sites, 19 (28%) are riparian obligate or riparian-dependent species. The most common riparian species observed include lazuli bunting (*Passerina amoena*), lesser goldfinch (*Spinus psaltria*), Lucy's warbler (*Leiothlypis luciae*), and Bewick's wren

(*Thryomanes bewickii*) (Table 3.8.4-3). Across riparian transects in the NCPN, there were no trends for most of the common riparian species and species of concern listed in Table 3.8.4-3; however, there was a significant decline for black-headed grosbeak. Virginia's warbler (*Leiothlypis virginiae*), a Utah PIF priority species, was observed infrequently during this study and in the UDWR study at the Fremont River site. Although Virginia's warbler is also commonly associated with pinyon-juniper woodlands, there were no observations along the two pinyon-juniper transects.

Table 3.8.4-3. Summary of common riparian species and species of concern observed at the Pleasant and Halls creeks transects from 2005 to 2019 compared with analyses for the Northern Colorado Plateau Network (as reported in Roberts et al. (2020)). Riparian affiliation was obtained from Rich (2002). Birds not listed in Rich (2002) but common in riparian habitat are referred to as "associated.".

Species	% Total Detections	NCPN Trend	Riparian Affiliation
American goldfinch [1]	0.12	Not Assessed	Dependent
Bewick's wren	1.2%	Stable	Dependent
Black-headed grosbeak	0.64	Declining	Dependent
Blue grosbeak	0.49	Stable	Obligate
Broad-tailed hummingbird [2]	1.70	Stable	Associated
Lazuli bunting	2.40	Stable	Dependent
Lesser goldfinch [1]	2.26	Stable	Dependent
Lewis's woodpecker	0.03	Not Assessed	Dependent
Lucy's warbler [2]	1.45	Stable	Dependent
Spotted towhee [1]	7.93	Stable	Associated
Virginia's warbler [2]	0.87	Stable	Associated
Warbling vireo	0.35	Stable	Dependent
Western wood-pewee [3]	0.58	Stable	Dependent
Yellow warbler	0.67	Stable	Obligate
Yellow-breasted chat	0.52	Stable	Obligate

[1] NAS Climate Watch species.

[2] Partners in Flight priority species.

[3] NPS/NAS highly climate-sensitive species.

Although the most common species occurring at the Pleasant/Halls creek sites and the Fremont River site differed, the total suite of riparian species was similar, with 18 obligate riparian and riparian-dependent species occurring in both studies. While NCPN surveys reported only one additional species (Lewis's woodpecker [*Melanerpes lewis*]), the UDWR surveys reported seven additional riparian species, including gray catbird (*Dumetella carolinensis*), common yellowthroat (*Geothlypis trichas*), and belted kingfisher (*Megaceryle alcyon*). The remaining three species were extremely rare at the Fremont River. These were Lincoln's sparrow (*Melospiza lincolnii*), American dipper (*Cinclus mexicanus*), and American redstart (*Setophaga ruticilla*).

For the two NCPN pinyon-juniper transects, observers reported 51 species from 2005 to 2019. Some of the most common species included black-throated gray warbler (*Setophaga nigrescens*), pinyon jay, Bewick's wren, gray vireo (*Vireo vicinior*), gray flycatcher (*Empidonax wrightii*), and juniper titmouse (*Baeolophus ridgwayi*). These species are strongly associated or dependent on pinyon-juniper woodlands, and three are of conservation concern (Table 3.8.4-4). Of these species, the only significant trend across the NCPN was for the black-throated gray warbler, which declined during the survey period. These results are consistent with mean abundance in the park (Figure 3.8.4-3).

Table 3.8.4-4. Summary of common pinyon-juniper species and species of concern observed at two transects from 2005 to 2019 compared with analyses for the Northern Colorado Plateau Network (as reported in Roberts et al. (2020)). Pinyon-juniper affiliation was obtained from Gillihan (2006).

Species	% Total Detections	NCPN Trend	Pinyon-Juniper Affiliation
Ash-throated flycatcher	4.12	Stable	Dependent
Black-throated gray warbler [1]	18.13	Declining	Associated
Gray flycatcher [1]	7.47	Stable	Associated
Gray vireo [1]	7.74	Stable	Associated
Juniper titmouse	7.30	Stable	Obligate
Pinyon jay	8.21	Stable	Dependent

[1] Partners in Flight priority species.

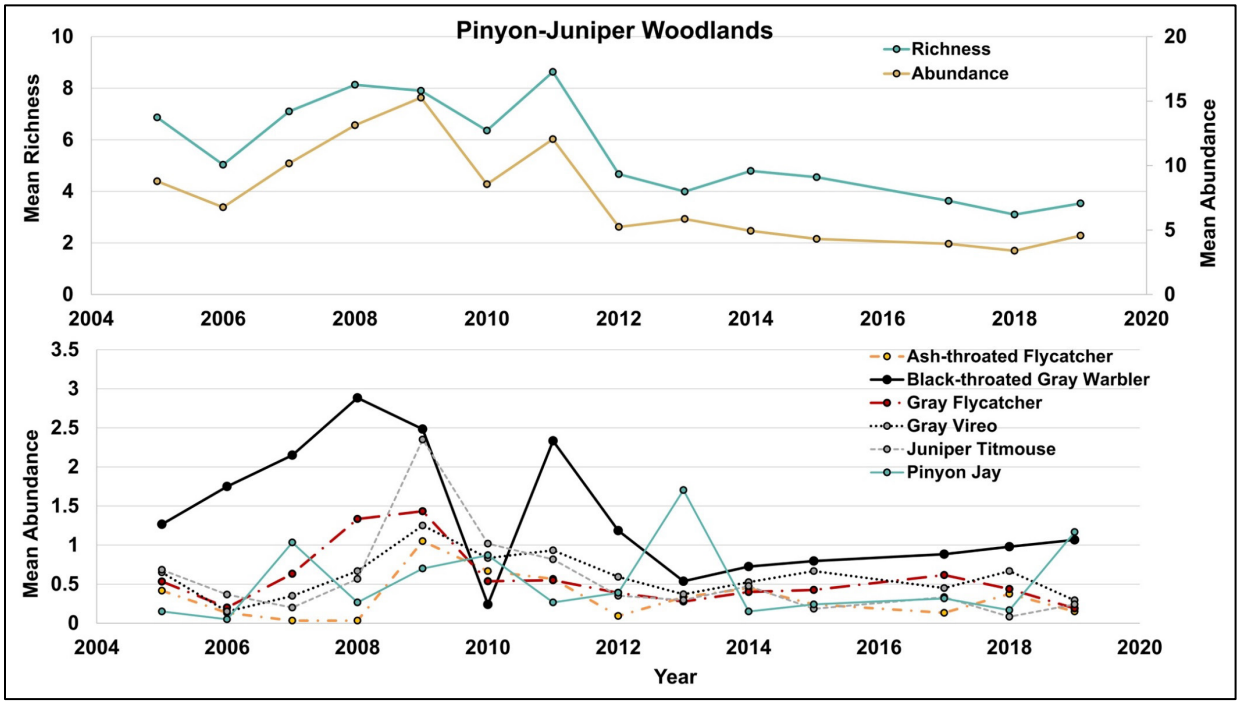


Figure 3.8.4-3. Mean annual richness and abundance (top) and mean annual abundance for the most common pinyon-juniper woodland species (bottom) at NCPN monitoring transects from 2005 to 2019.

During BBS surveys (1987–2019), 48 and 82 species have been recorded on the Desert View (mean = 22/year) and Notom (mean = 30/year) BBS routes, respectively. Abundance along the Notom route was also substantially higher (228 individuals/year) than on the Desert View route (129 individuals/year). The only significant trend for richness and abundance was a slight increase in mean annual richness for the Desert View route ($F(1,20) = 10.2$, $p = 0.005$, $R^2 = 0.34$) (Figure 3.8.4-4).

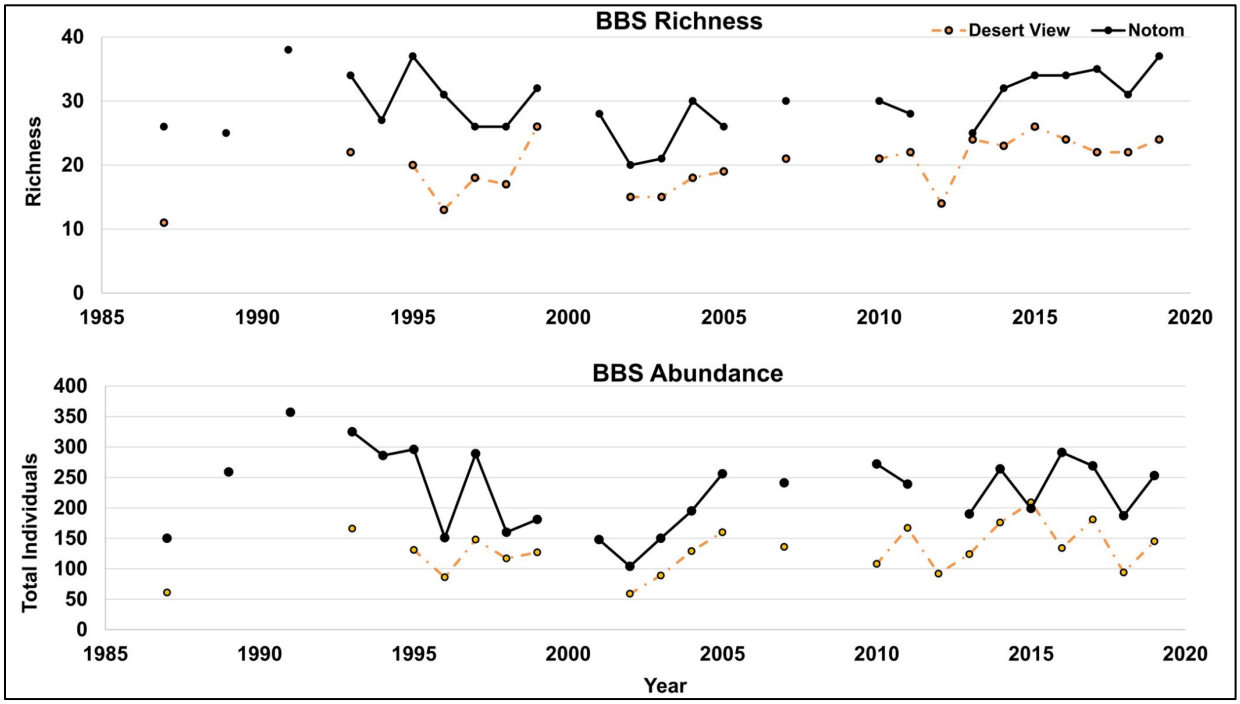


Figure 3.8.4-4. Mean annual richness (top) and number of individuals observed (bottom) on the Desert View and Notom BBS survey routes from 1987 to 2019.

Five species occurred with enough frequency on each route (seven species in total) to allow for regression analyses (i.e., >80 detections) (Table 3.8.4-5). On both routes, black-throated sparrow significantly increased. Say's phoebe also increased on the Desert View route, but trend was stable on the Notom route. Lark sparrow (*Chondestes grammacus*) significantly declined on the Notom route, but trend was stable on the Desert View route (Figure 3.8.4-5). Statewide USGS results (Pardieck et al. 2020) were consistent with CARE's results for black-throated sparrow, Say's phoebe (Desert View only), and western meadowlark (*Sturnella neglecta*) and somewhat consistent for horned lark (*Eremophila alpestris*) and loggerhead shrike (*Lanius ludovicianus*).

Table 3.8.4-5. Regression results for shrubland-grassland birds on the two BBS routes from 1987 to 2019, as well as USGS statewide trends.

BBS Route	Species	Mean (SD)	F (df)	*p*	R^2	CARE Trends	USGS Statewide Trends (1966–2019)
Desert View	Black-throated sparrow	24.59 (13.97)	14.02 (1,20)	0.001 [(1)]	0.41	Increasing	Stable to Increasing
	Horned lark	12.09 (5.28)	1.48 (1,20)	0.240	0.07	Stable	Stable to Declining
	Lark sparrow	10.36 (6.59)	3.35 (1,20)	0.080	0.14	Stable	Increasing
	Loggerhead shrike	3.55 (2.34)	0.89 (1,20)	0.360	0.04	Stable	Stable to Declining
	Say's phoebe	4.64 (3.19)	8.23 (1,20)	0.010 [(1)]	0.29	Increasing	Increasing
Notom	Black-throated sparrow	35.64 (19.22)	12.75 (1,23)	< 0.010 [(1)]	0.36	Increasing	Stable to Increasing
	Lark sparrow	24.92 (12.85)	7.33 (2,23)	0.010 [(1)]	0.24	Declining	Increasing
	Say's phoebe	7.68 (6.10)	0.02 (1,23)	0.890	0.01	Stable	Increasing
	Western kingbird	4.92 (3.43)	0.79 (1,23)	0.380	0.03	Stable	Increasing
	Western meadowlark	8.96 (9.51)	11.31 (1,21)	<0.01 [(1)]	0.35	Declining	Stable to Declining

[1] Indicates significance ($\alpha < 0.05$)

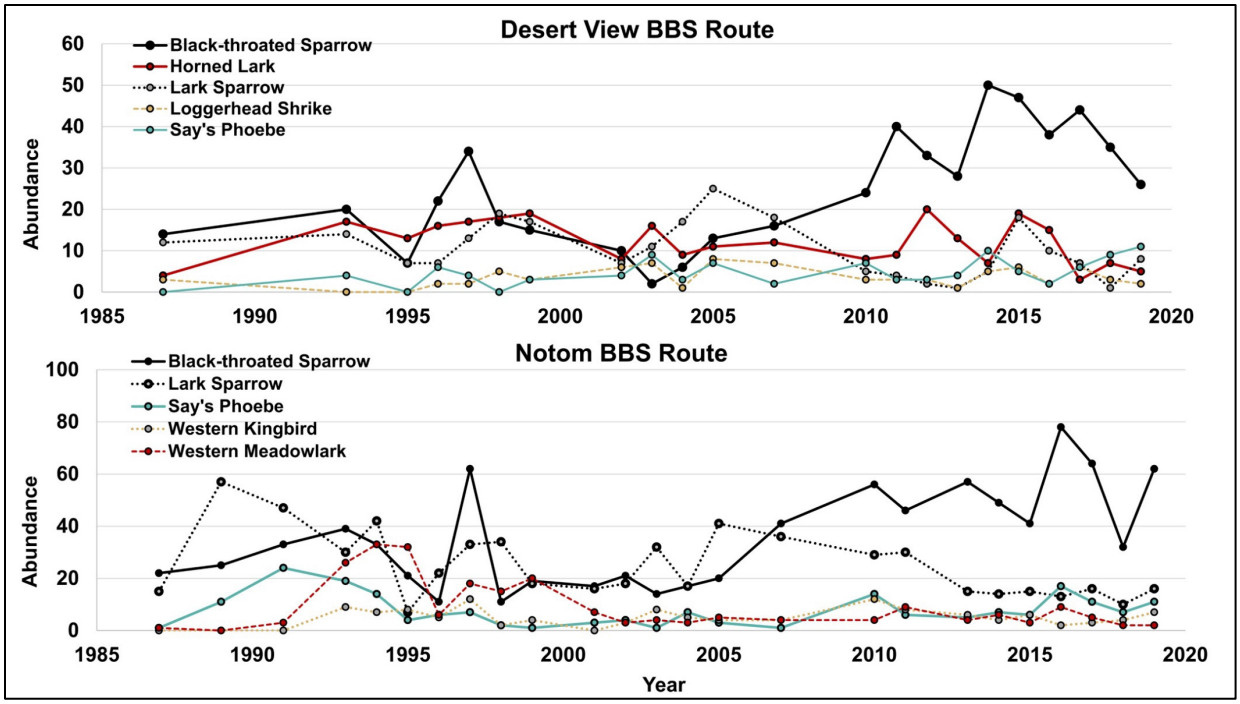


Figure 3.8.4-5. Mean annual abundance for select shrub-grassland species on the Desert View and Notom BBS survey routes from 1987 to 2019.

While BBS data are useful at the scale of the ecoregion, these surveys do not answer the park's question regarding songbird abundance and community composition in the park. As noted during the manager-scientist meeting, most of the birds along these routes are counted at a few locations where the route crosses a riparian area (NPS, M. Wehtje, biologist, comments during manager-scientist meeting, 24 August 2021). Furthermore, the length of the routes (50 stops over 40 km [~25 mi]) means that the latter half of the surveys occur in mid-morning or later when birds are less vocal/active and when noise from traffic has increased. Lastly, these surveys follow roads, which may not represent the songbirds in areas more remote from roads and other developments, and more than half of the BBS stops are outside the park on grazed lands managed by the BLM.

The Desert View BBS runs through the Hartnet grazing allotment, which was discontinued in May 2018. The last stretch of the Notom BBS route (~4.8 km/3 mi) runs through CARE's Sandy 3 allotment where grazing persists, although this portion of the route is surveyed later in the day. In a study of bird response to grazing in and around CARE, Willey (1994) found that black-throated sparrows (*Amphispiza bilineata*) and horned larks (*Eremophila alpestris*) were absent in the grazed site. Although lark sparrows, Say's phoebes, rock wrens, and vesper sparrows (*Pooecetes gramineus*) were observed at both grazed and un-grazed sites, densities were consistently lower in the formerly grazed-sites. These findings were correlated with lower structural vegetation complexity in grazed sites (Willey 1994); however, we have no such information to correlate BBS data to effects from grazing in the park.

In a study of upland vegetation in the Hartnet allotment, Witwicki (2020) found that most measures of grass and shrub cover were in fair but deteriorating condition, although the total shrub cover and shrub density appeared to be in good condition. These results are consistent with rangeland health surveys completed in 2015, which reported that 64% of the plots in the Hartnet allotment were in a state of moderate or moderate to extreme departure from reference conditions (NPS 2018b). Similarly, 59% to 69% of the plots in the Sandy 3 allotment were in a state of moderate or moderate to extreme departure from reference conditions (NPS 2018b). In comparison, plant surveys in the Cathedral/Rock Springs allotment (completely retired by 1999) showed good and improving conditions for most indicators of upland vegetation, suggesting that the plant community in the Hartnet allotment may improve over time (Witwicki 2020), which may also result in higher populations of birds associated with this habitat type.

Over the two years in which NAS Climate Watch surveys have occurred in the park, 151observations of 45 species were reported. Richness was nearly twice as high in the northern site (38) than in the adjacent southern site (23), and it was higher during summer (39) than during winter (9). Of the six NAS Climate Watch species, none were observed during winter, and three were observed during summer (Table 3.8.4-6). Western bluebird, white-breasted nuthatch (*Sitta carolinensis*), and American goldfinch have not been reported during either season. Because this survey is intended to validate climate models of how individual species are expected to respond to climate change, documenting the absence of a species is as important as documenting its presence.

Table 3.8.4-6. Summary of NAS Climate Watch data collected in summer and winter of 2019 and 2020.

Species	Summer	Winter	Predicted Climate Response by 2050	
			Summer	Winter
American goldfinch	Not observed	Not observed	Potential extirpation	Not found [1]
Lesser goldfinch	Present	Not observed	Improving	Potential colonization
Spotted towhee	Present	Not observed	Stable	Not modeled
Mountain bluebird	Present	Not observed	Stable	Improving
Western bluebird	Not observed	Not observed	Stable	Potential colonization
White-breasted nuthatch	Not observed	Not observed	Stable	Not found [1]

[1] The species is not found or only occasionally sighted and is not projected to colonize by 2050 (Schuurman and Wu 2018).

For example, lesser goldfinch may become a winter resident by 2050 (Schuurman and Wu 2018), so its current absence is expected. The absence of a currently expected Climate Watch species may also be due to lack of habitat along the survey routes and/or the limited surveys conducted to date. These are the only data on wintering birds in the park. Although there is a Christmas Bird Count circle that includes the northern portion of the park, data are not parsed by area, though it would be relatively

simple for participants to keep a separate list of species and abundance for the park portion of the survey in the future, potentially documenting species of concern, such as black rosy-finch (*Leucosticte atrata*), that are not well addressed by the studies reported here.

Although temperature and precipitation are important drivers of bird response to climate change, Roberts et al. (2021) argue that integrating water availability and temperature into a water deficit metric may be more informative since it accounts for both temperature and precipitation and can be applied at the local scale. In their analysis of 30 species across three habitat types in 11 national parks and monuments on the Colorado Plateau, Roberts et al. (2021) found that the relationship between bird density and water deficit differed by species-habitat relationships, with some species exhibiting a positive response and others a negative response. Species that appear particularly sensitive to water deficit included lazuli bunting in riparian habitat and spotted towhee in pinyon-juniper and riparian habitats. In contrast, the ash-throated flycatcher in riparian habitat and the house finch and gray vireo in pinyon-juniper habitat all exhibited positive responses to annual water deficit, which suggests that these species are less vulnerable to projected increases in annual water deficit (Roberts et al. 2021). Species that breed in multiple habitats could potentially shift to a different primary breeding habitat if water deficit exceeds certain thresholds. Habitat specialists, however, are likely to decline with increased water deficit.

In summary, there are songbird data for limited areas of three habitats in CARE. While these data show that the suite of obligate and dependent species within each of the three habitat types are present, there are data gaps concerning population size, and there are no data on reproduction or nesting success. Due to the small sample sizes, we could not extrapolate results to the respective habitat park-wide, but density estimates provided by Pope et al. (2015) could serve as approximations for population size for riparian species. In addition, NCPN density estimates could also be used for riparian areas in the park and for pinyon-juniper woodlands. Some species of concern and/or obligate and dependent species in each of the three habitat types have exhibited declines at larger spatial scales (i.e., state and NCPN). There are also indications of declines for some species at the park level, including western meadowlark and lark sparrow. However, trends in abundance or density could result from factors other than conditions inside the park, especially for neotropical migrants, which cover broad geographic areas throughout their life cycle.

The condition of CARE's songbird community composition is good/fair, with an unknown trend (Table 3.8.4-7). Confidence in the rating is low because none of the studies were designed for inference at the park. Additional sampling along other sections of the streams currently sampled, as well as expansion to other streams, would provide a more rigorous framework for understanding riparian birds in the park. Additionally, expansion of the pinyon-juniper and grassland/shrubland sites that are not along roads would allow for more robust trend analyses in the future.

Table 3.8.4-7. Condition status of the songbirds indicator.

Indicator	Condition Rating [1]	Trend	Condition Evaluation
Community Composition	Good/Fair	Unknown	Changes in songbird community composition may have occurred, but degradation is not yet measurable. For example, nearly all potential species are present (including key indicators), but trends for some indicate possible declines that are not statistically significant. Confidence level is low because none of the studies were designed for inference at the park level.

[1] Refer to Appendix B, Table B-5, for the full suite of condition rating statements.

3.9. Mexican Spotted Owl (Gap Analysis)

3.9.1. Background & Importance

The Mexican spotted owl (MSO; *Strix occidentalis lucida*) was listed as threatened under the Endangered Species Act in 1993 (USFWS 2012). The USFWS implemented a recovery plan for the owl in 1995, and the plan was updated and revised in 2012 (USFWS 2012). The MSO was listed as threatened because of potential negative impacts from modifications to forest habitats and inadequate existing regulatory mechanisms. Secondary factors included "the potential for catastrophic wildfire and potential competition and/or predation by other raptors, including the great horned owl (*Bubo virginianus*) and red-tailed hawk (*Buteo jamaicensis*)" (USFWS 1993). Critical habitat, which includes most of CARE, was designated in 2004 and comprises about 3.5 million ha (8.6 million ac) on federal lands in Arizona, New Mexico, Colorado, and Utah (USFWS 2012). CARE is in the Colorado Plateau Ecological Management Unit (CP EMU), which roughly coincides with the boundary of the Colorado Plateau Physiographic Province (USFWS 2012). Throughout the CP EMU, areas with suitable canyon or forest habitats are interspersed with large expanses of unsuitable habitat (USFWS 2012). MSO habitat in Utah occurs primarily in deep, steep-walled or hanging canyons. Of the 206 owl sites documented in the CP EMU, as of 2011, 64% were on NPS-administered lands, including GLCA, Zion National Park (ZION), Canyonlands National Park (CANY), and CARE. A more current population estimate for the CP EMU is unavailable, and the 2011 estimate of 206 owl sites is probably lower than the current population size.



Mexican spotted owl. Image Credit: NPS / SHAUNA COTRELL.

3.9.2. Status of Knowledge

CARE staff, cooperators, and researchers have monitored the occurrence and reproduction of MSO in the park since 1977. The information gathered pre-1993 USFWS listing was from observations by second-hand sources. Systematic surveys began in the early to mid-1990s, during which time nine protected activity centers (PACs) were identified in CARE (Lenhart 2000; Willey 1998; Willey and van Riper III 2000).

According to USFWS (2012), PACs should consist of at least 243 ha (600 ac) of suitable habitat around known MSO nest/roost sites. The owl's primary prey includes small terrestrial mammals (especially *Neotoma* and *Peromyscus* species), but they will also hunt small birds, bats, arthropods, and reptiles (USFWS 2012; Willey 2013).

The MSO exhibits high site fidelity (USFWS 2012), and in most instances, MSOs were observed using the same nest sites and roosts at CARE as previously observed. Annual surveys since the early 2000s have generally focused on detecting MSOs at a subset of the nine PACs, with documenting reproduction as a secondary goal (Hockenbary 2011). Surveys were done by imitating an MSO call and then listening for a response.

Using CARE's Access database (NPS, S. Borthwick, biologist, data file sent to Lisa Baril, Utah State University, 1 February 2021), we summarized whether MSO adults and fledglings were observed at each site surveyed from 1977 to 2020. We used "detection" rather than "occupancy" because traditional approaches to obtaining occupancy were not implemented at CARE. Site or territory occupancy relies on multiple, appropriately timed visits to determine if a site is occupied by a breeding pair, a single individual, a non-breeding pair, or no owls. Please note that during the manager-scientist meeting, both CARE's superintendent and chief of resource management and science preferred to include the MSO site names in this report because they are publicly referenced during the park's closure announcements (NPS, S. Fritzke and J. Roche, comments during the manager-scientist meeting, 24 August 2021).

The monitoring plan for MSO requires a minimum of four site visits from March through August separated by at least five days to determine occupancy and reproductive success for a given territory (USFWS 2012). Nesting status surveys require that two of those visits occur sometime between 1 April and 1 June, and fledging success requires two visits at least one week apart after owlets are expected to have fledged (USFWS 2012). For most sites surveyed in and around CARE, observers made one or two visits, often on consecutive days because of the remote nature of some sites.

Since 1977, 30 sites have been surveyed for MSOs in and around the park, and owls have been detected in 16 of those sites in at least one year. No MSOs were detected in the remaining 14 sites (Table 3.9.2-1), although the absence of owl detections does not necessarily indicate that these sites do not support owls. The 14 sites in which no MSOs were detected were surveyed for only one to three breeding seasons between 2001 and 2014, often with one visit per season.

Table 3.9.2-1. Summary of exploratory visits to potential MSO sites.

Site Name	Site Summary
Brimhall Arch Area	Surveyed in mid-June 2010 but no owls were detected.
Capitol Gorge	Surveyed in 2001, 2011, 2015, and 2018 but no owls were detected.
Chimney Rock and Chimney Rock Canyons	Surveyed in 2014 and 2018 but no owls were detected.
Cottonwood Canyon	Single visit in 2020 but no owls were detected; a spotted owl was observed near this location on BLM land in early May 2020 and an acoustic recording device was deployed 15–28 May, but no owls were detected
French Spring Fork (BLM)	No owls were detected on April 2001 visit, but owls were reported at this location in 1992. This is a potential PAC site but still need to know the number of owls and date of the 1992 observation.
Hickman Trailhead	Surveyed in mid-June 2008 but no owls were detected.
Lower Spring Canyon	Surveyed in 2010 and 2015 but no owls were detected; following up on a report of a spotted owl in 2015 but was confirmed to be a horned owl.
North Coleman and Bear Canyons	Surveyed in 2008, 2010, and 2011 but no owls were detected.
Stair Canyon (BLM)	Surveyed twice (April and July) in 2001 but no owls were detected.
Surprise Canyon	Surveyed in 2001 and 2008 but no owls were detected.
Twin Corral Box Canyon (BLM)	Surveyed in 2001 but no owls were detected.
Upper Cottonwood	Surveyed in 2008 but no owls were detected.
Upper Middle Moody Canyon	Multiple visits in 2006 but no owls were detected; area of proposed Viking Oil Project Area.
Water Canyon	Surveyed in 2008 and 2013 but no owls were detected.

Of the 16 sites where owls have been observed in at least one year since 1977, nine are designated as PACs. Figure 3.9.2-1 shows the number of years for which adults were confirmed at each site, as well as at which sites observers reported fledglings. Adults were confirmed at Bitter Creek Divide, Burro Wash, First Canyon, and Five Mile Wash in more than half of the years surveyed (Figure 3.9.2-1). These were also the sites (except for Cassidy Arch/Shinob Canyon), with the most years of surveys. Fledged young were confirmed in roughly half the years that the Bitter Creek Divide and Five Mile Wash sites were surveyed. In all but one of the 10 years First Canyon was surveyed, young were observed. An average of two visits were made per site per year, but visits were made on consecutive days in the more remote sites, which could be considered a single visit.

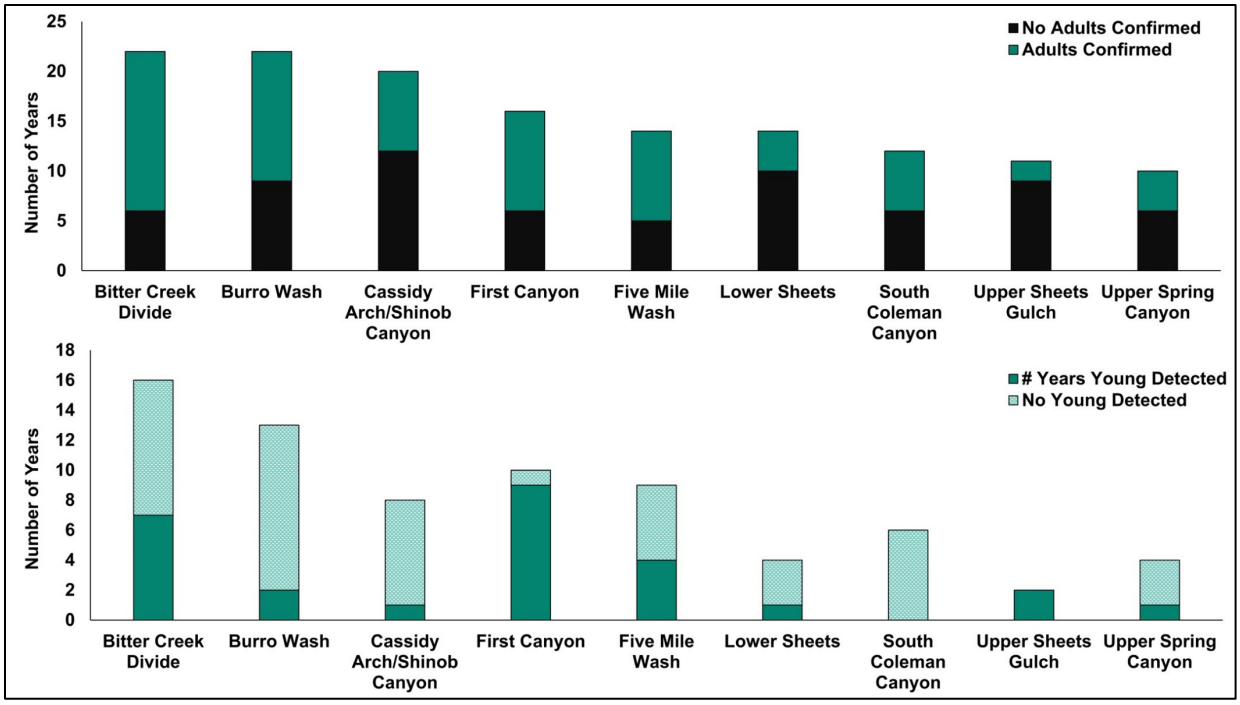


Figure 3.9.2-1. Summary of MSO detections of adults (top) and young (bottom) at the nine PACs in CARE.

In addition to the nine PACs, there are 14 sites in which at least one MSO has been observed in at least one year (Table 3.9.2-2). Sites not currently designated as PACs may be eligible for PAC status if: more than one adult or subadult owl is observed in potential breeding habitat during the breeding season; auditory detections occur within 500 m (0.31 mi) of each other during the breeding season; or young-of-the-year were detected prior to 1 September (USFWS 2012). Four sites meet USFWS (2012) requirements for designation as a PAC: Lower Muley Twist, Miller Canyon, Marinus Canyon (BLM), and Sams Mesa Box Canyon (BLM). Because two of these sites occur on BLM lands outside the park, this could bring the total number of PACs in CARE to 11.

In a comparison of four study areas in Utah (ZION, CARE, GSENM, and the Cedar Mesa-Elk Ridge highland), Hockenbary (2011) found that MSO occupancy was higher in mesic (wetter) sites than in xeric (drier) sites. Also, mesic sites were more quickly recolonized than xeric sites, probably because MSO prey density fluctuates less in mesic sites than in xeric sites (Hockenbary 2011). This is supported by a study of owl occupancy and prey species availability in CARE and GSENM (Thornburg 2018).

Thornburg (2018) found that occupancy was correlated with the relative abundance of prey species. *Cricetid* rodents, specifically woodrats (*Neotoma* spp.) and white-footed mice (*Peromyscus* spp.) are the most abundant prey in the canyonlands of southern Utah. Thornburg (2018) found that winter precipitation was the primary driver of *Cricetid* rodent demographics, with greater abundance following years with above average winter precipitation (i.e., >200 mm [7.9 in]). Thus, abandoned

MSO territories may be reoccupied in the 1–2 years following above average winter precipitation, which is supported by observations in CARE.

Table 3.9.2-2. Summary of MSO at sites not currently designated as PACs in and around CARE.

Site Name	Year	Adults Detected	Young Produced	Number of Visits
Lower Muley Twist [1]	1991	Yes (Pair)	2	2
	1995	No	–	–
	1996	No	–	–
	1997	No	–	–
	1998	No	–	–
	2000	No	–	2
	2001	No	–	1
	2008	No	–	2
	2009	No	–	2
	2010	No	–	2
	2011	No	–	1
	2012	No	–	1
Marinus Canyon (BLM) [1]	1994	Yes (Pair)	Unknown	–
	2001	Yes (Pair)	Unknown	2
Miller Canyon [1]	2008	Yes (Pair)	Unknown	2
	2009	Yes (Pair)	Unknown	1 or 2
	2010	No	–	1
Oak Creek	2018	No	–	1
	2015	Yes (Single Owl)	–	2
	2016	No	–	1
	2017	No	–	1
	2020	No	–	1
Pandora's Canyon	2013	Yes (Single Owl)	–	3
	2014	No	–	1
	2015	No	–	2
	2016	No	–	2
	2018	No	–	1
	2020	No	–	1
Sams Mesa Box Canyon (BLM) [1]	1992	Yes (Pair)	Unknown	1
	2001	Yes (Pair)	Unknown	1
Upper Muley Twist	2008	No	–	1
	2016	Yes (Single Owl)	–	–

[1] Site meets the USFWS (2012) requirements for PAC designation.

For example, Bitter Creek Divide is one of the most active sites in the park but was abandoned in 2012. Thornburg (2018) reported that Bitter Creek Divide supported the highest abundances of brush mice of all five CARE sites surveyed from 2013 to 2015. Woodrat abundance at Bitter Creek Divide was also consistently high and increased between 2013 and 2015. In 2015, woodrat abundance peaked following high winter precipitation and the site was re-occupied by MSO. In 2016, Bitter Creek Divide successfully fledged young (Thornburg 2018). In addition, two other sites that were occupied by a single adult male in 2015 supported breeding pairs in 2016 (Lower Sheets and Cassidy Arch/Shinob Canyon), one of which fledged young (Cassidy Arch/Shinob Canyon). Canyoneers also reported a previously unknown MSO location in 2016 at Upper Muley North (Willey 2016). These results suggest that higher winter precipitation leading to higher prey abundances made some territories suitable for owl re-occupation. This is particularly significant given that sites in CARE are generally drier than in other parks like ZION (Hockenbary 2011).

3.9.3. Discussion

To facilitate a future condition assessment of the MSO in CARE, we included an indicator, with two measures (Table 3.9.3-1). The reference criterion for occupancy is based on the USFWS delisting criterion of a stable or increasing trend after 10 years of monitoring (USFWS 2012). The USFWS has not defined reference criteria for reproductive success because of the costs associated with collecting these data (USFWS 2012); however, it is reasonable that a stable or increasing trend in this measure would also indicate good condition for the status of MSO in the park. While consistent monitoring over the long-term is the goal, this type of commitment requires funding, which is often difficult to obtain (NPS, S. Borthwick, biologist, comments to draft evaluation, 9 April 2021).

Table 3.9.3-1. Proposed study details for Mexican spotted owl.

Indicator of Condition	Measure	Reference Criteria for Measure
Population Size and Reproduction	Occupancy	Stable or increasing trend after 10 years of monitoring.
	Reproductive Success	Stable or increasing trend after 10 years of monitoring.

In CARE, riparian habitat in several steep-walled canyons provide breeding habitat for the MSO (e.g., First Canyon, Five-Mile Canyon), but most of the sites do not possess riparian habitat and are dominated by desert scrub or desert scrub interspersed with mixed-conifer habitat (e.g., Burro Wash, Shinob, and Sheets Gulch (Willey 1998; Willey and van Riper III 2007, 2014, 2015)). With respect to riparian habitat, the amount and quality of vegetation in some canyons within the park is influenced by past grazing and trailing activities (e.g., Oak Creek). Grazing could have impacted, and may continue to impact, MSOs through legacy effects by reducing prey availability and abundance and degrading the riparian plant community (USFWS 2012). During the summer of 2020, Joe Ceradini, Utah Valley University biologist, conducted small mammal trapping along Oak and Pleasant creeks (six sites trapped for two nights at each of the creeks) to evaluate differences in small mammal populations and communities with different levels of disturbance from cattle. Preliminary results show substantially higher small mammal abundance at Pleasant Creek, where there has been

less cattle disturbance than at Oak Creek. This is of interest because the locations may serve as MSO foraging habitat.

Seven of the nine PACs are within 3.2 km (2 mi) of a grazing allotment or a current livestock trailing route (NPS 2018b). Although there are no PACs in the Sandy 3 allotment, there are two that are 0.40 km (0.25 mi) and 1.21 km (0.75 mi) away from the allotment (NPS 2018b). One was unoccupied in all six years surveyed between 2008 and 2016, and the other was regularly occupied by either a pair or a single individual (NPS 2018b).

None of the livestock trailing routes pass through the nine known PACs. The Oak and Pleasant creek routes may provide foraging habitat for MSOs (NPS 2018b), although there are no radio telemetry data suggesting that they forage in either of these riparian zones (Montana State University, David Willey, biologist, comments to draft evaluation, 17 March 2021). However, a single MSO was reported in Oak Creek in 2015 (Table 3.9.2-2). According to NPS (2018b), none of the PACs in CARE are affected by livestock grazing and trailing in the park. Grazing in CARE is now limited to one allotment in the park (Sandy 3), while cattle continue to be trailed seasonally, including in potential MSO habitat (e.g., Oak and Pleasant creeks) (NPS 2018b). Trespass cattle are occasionally found in the area, and as a result, grazing of herbaceous plants and browsing of immature willows have increased since the 2017 rapid assessment in Upper Pleasant Creek.

Healthy riparian corridors with perennial water that support large trees and well-developed understories may serve as climate refugia for MSO, but they also serve as prime habitat for great horned owls, which likely excludes MSOs (Montana State University, D. Willey, wildlife biologist, comments to draft evaluation, 19 May 2021). This may explain why MSOs have not been observed nesting in these canyons (Montana State University, D. Willey, wildlife biologist, comments to draft evaluation, 19 May 2021). However, mesic conditions allow for prey species to persist during periods of below average precipitation.

Precipitation, especially during winter, could be used as a tool for planning site surveys. Thornburg (2018) proposed that "two consecutive years of above average winter precipitation (>200 mm [7.9 in]) might be used to indicate increases in primary prey abundance and result in increased MSO recolonization at extirpated sites. Conversely, two to three consecutive years of below average winter precipitation (<100 mm [4.0 in]) could be used as an indicator of low primary prey abundance…and possible extirpation events of MSO territories…" (Thornburg 2018). But projected future droughts (and current extended droughts) may have a strong negative effect on MSO throughout its range (Peery et al. 2012), exceeding the capacity of some riparian areas to serve as climate refugia, especially since CARE's riparian areas are relatively xeric compared to other locations (e.g., ZION). Precipitation during other seasons may also be useful in predicting prey population fluctuations.

Willey and Willey (2010 as cited in NPS 2018b) reported that in GSENM drought had a negative effect on owl occupancy, pair status, and offspring. Climate, particularly precipitation, was found to be a major factor affecting desert rodent population dynamics, including MSO prey species (Willey 2013). The MSO prey base is also likely influenced by reduced soil moisture and an increase in

actual evapotranspiration as temperatures rise (NPS, D. Thoma, landscape ecologist, comments to NRCA study plan, 24 February 2021).



Lower Muley Twist Canyon in CARE. Image Credit: NPS / SHAUNA COTRELL.

In a study of the potential climate change effects on all three subspecies of the spotted owl, Peery et al. (2012) found that the MSO was the most vulnerable, even in the core of its range. They also found that MSO survival increased with the amount of precipitation in the previous year and declined with increasing maximum temperature during the growing season. In other words, warm and dry conditions were associated with lower survival of MSO in Arizona and New Mexico. Similarly,

reproductive output increased with growing season precipitation and decreased with increasing minimum nesting season temperatures (Peery et al. 2012). The authors then projected future spotted owl populations under each of the three emission scenarios put forth by the Intergovernmental Panel on Climate Change. In all three scenarios, both survival and fecundity were likely to decline rapidly in the next century (Peery et al. 2012). Even under current climate conditions, MSO populations in Arizona and New Mexico were likely to exhibit gradual declines irrespective of other threats (Peery et al. 2012).

The effects of climate change on the MSO may be partially mitigated by changes in visitation to CARE. Although visitation has increased dramatically in recent years, exceeding one million visitors per year since 2016 (NPS Stats 2021a), predicted future visitation is expected to decrease by 7–8% during the summer and by as much as 25–35% during the shoulder seasons as a response to extreme temperatures (Fisichelli and Ziesler 2015). MSO courtship begins in March, with egg-laying in late March to early April (USFWS 2012). Eggs hatch in early May, and young depend on adults throughout the summer, dispersing in early fall (Willey and van Riper III 2000). Currently, visitation is highest during the MSO breeding season (NPS Stats 2021a), but visitors are less likely to stray from developed areas on the hottest days, which may benefit owls and young that may already be experiencing heat stress (Wilkins and Smith 2020). However, canyoneering may be increasing in popularity, which may warrant more focused monitoring in MSO breeding territories.

Although the remote location of most MSO territories in CARE limits the amount of visitor disturbance, and MSOs can become habituated to regular disturbances, Hockenbary (2011) found that diurnal fledgling behavior differed between sites with high human visitation and sites with low human visitation. Fledglings in high-recreation territories spent more time exhibiting maintenance behaviors and less time exhibiting vigilance behaviors than fledglings in low recreation territories. Confounding variables prevented an analysis of adult behaviors between levels of recreation because all high-recreation territories produced young, and all low-recreation territories did not (Hockenbary 2011). However, this finding suggests that some types of recreation may not influence whether a pair successfully fledges young, although there could be stressors to fledglings associated with recreation that may influence survival. Notably, the sample sizes in Hockenbary (2011) were small.

Noise is another type of disturbance that may affect owl behavior (e.g., displacement could make owls more vulnerable to predators) (USFWS 2012). While infrequent noise events are unlikely to cause long-term impacts, persistent noise may have negative effects on MSOs (USFWS 2012). According to the USFWS recovery plan, “noises ≥ 80 dBO (decibels weighted for middle sound frequencies where owl hearing is the most sensitive), had a greater than 0.60 probability of causing an owl to flush. This noise level is roughly equivalent to 69 dBA (i.e., decibels weighted for human hearing) or approximately as loud as an ordinary human conversation” (USFWS 2012). Additionally, the canyon habitat that owls prefer in CARE may be more likely to amplify noises than other habitat types (USFWS 2012), although rappelling down canyon walls is a much more intrusive disturbance than hikers walking along canyon bottoms.

The NPS NSNSD estimates acoustic conditions across parks using a geospatial sound model, which predicts daytime sound levels during midsummer. The model includes numerous explanatory

variables (e.g., roads, airports, railroads) and field measurements of sound pressure levels. In CARE, the predicted existing sound level mean was 25.7 dBA, and the maximum level was 31.3 dBA, suggesting that noise may not be a significant stressor to MSOs in the park. Hockenbary (2011) reported that only two of 10 sites in CARE receive regular visitors (<10/week), although visits to known MSO sites may have increased since that study because of the increase in park visitation. Even short-duration noise from traffic, backcountry campers, and canyoneers could negatively influence owl behavior, which is one reason CARE manages the sensitive, high-use nesting areas by closing them to visitors, including canyoneers (Montana State University, David Willey, biologist, CARE manager-scientist meeting, 24 August 2021). Please refer to Chapter 4 for management considerations related to acoustic monitoring of MSO.

CARE shares its boundary with the Fishlake NF to the west, GSENM to the southwest, GLCA to the south, and BLM holdings on the eastern and northern boundary (NPS 2018b). These land management agencies have legislated uses that include grazing, mining, and OHV use on the Fishlake NF (USFS 2020). While the USFWS restricts certain activities within known PACs, it's important to note that PACs are designed to primarily protect nesting and roosting habitat (USFWS 2012). Although foraging habitat is likely included in designated PACs, MSOs may use foraging sites that are subject to more intensive land use located outside a PAC (USFWS 2012), and PACs that overlap with the park boundary could be influenced by these types of adjacent land uses.

In summary, the MSO faces numerous threats throughout its range, with climate change, habitat modification, and catastrophic wildfire as the most potentially influential. Data gaps include the absence of regular monitoring at remote sites, limited data on reproduction and occupancy estimates, understanding the kinship between individuals in CARE, and understanding the dispersal of fledglings. In a literature review of all three spotted owl subspecies, Wan et al. (2018) found that the absence of population dynamics was a major data gap for the MSO throughout its range. Wan et al. (2018) also found that the MSO was the least studied subspecies in terms of response to threats.

The canyonlands of southern Utah are some of the most challenging landscapes in which to monitor MSOs. To address this issue, in 2020 CARE staff deployed acoustic monitoring devices at five sites in the park (Borthwick 2020). Because these devices record data for several weeks at a time, they reduce the need for multiple site visits, as well as reduce potential disturbance to MSOs caused by multiple site visits. Using acoustic monitoring devices, collecting materials for genetic analysis, and structuring data to develop occupancy estimates will help park staff better understand MSO dynamics in and around CARE and guide future activities to achieve conservation goals.

3.10. Desert Bighorn Sheep (Gap Analysis)

3.10.1. Background & Importance

The former abundance and distribution of desert bighorn sheep (BHS; *Ovis canadensis nelsoni*) in and around CARE was recorded on the sandstone walls of the Waterpocket Fold by the Fremont Culture, which inhabited much of Utah from approximately 200 to 1350 Common Era (Bellew et al. 1995). BHS declined dramatically throughout their range, including Utah, in the latter half of the nineteenth century following the introduction of domestic sheep, which transmitted novel diseases, such as pneumonia—a non-native respiratory disease caused by bacterial pathogens (often *Mycoplasma ovipneumoniae*)—and parasites to BHS (Cassirer et al. 2018; Singer and Gudorf 1999).



Petroglyphs of bighorn sheep can be found along Highway 24. Image Credit: NPS / SHAUNA COTRELL.

Within present-day CARE, the first domestic sheep were brought by Mormon settlers in 1876 when they established the community of Fruita (Bellew et al. 1995). Although disease was the primary cause for declines in BHS throughout their range, changes in habitat and unrestricted hunting also contributed to population declines. By 1934, BHS were functionally extinct from CARE, except for a ram that was killed in Capitol Gorge by a sheepherder in 1948 (Bellew et al. 1995). Beginning in 1966, UDWR began reintroducing BHS to their former range (UDWR 2018a). In the mid-1980s and mid-1990s, the NPS reintroduced BHS to CARE (Singer and Gudorf 1999), and as populations of

BHS have increased, preventing them from co-mingling with domestic sheep and goats has presented a significant management challenge (UDWR 2018a).

3.10.2. Status of Knowledge

In 1975, UDWR, in cooperation with the NPS, BLM, and the former National Biological Survey (now the Biological Resources Division within the USGS), reintroduced four sheep (one ram and three ewes) to Moody Canyon in GLCA, which is adjacent to the southern district of CARE and the Escalante District of the BLM (site # 1 in Figure 3.10.2-1) (Bellew et al. 1995). In 1976 and 1978, an additional 19 sheep were released at this site (five rams and 14 ewes) (Bellew et al. 1995).

Reintroductions within CARE's boundary began in 1984, with the release of 22 sheep (three rams, 14 ewes, and five lambs) in the Red Slide area (site # 2 in Figure 3.10.2-1), which is northeast of the Moody Canyon release site (Bellew et al. 1995). The Red Slide site received an additional nine sheep (two rams and seven ewes) in 1985. Connectivity between the Moody Canyon and Red Slide release sites was demonstrated when two collared ewes travelled between the two locations in 1984 (Bellew et al. 1995). BHS from the Red Slide release site also migrated to Stevens and Miller canyons, as well as north into Lower Muley Twist Canyon within CARE's boundary (Bellew et al. 1995). This became known as the Escalante herd, which includes the southern portion of CARE and the Escalante River drainage in GLCA. In 1994, aerial surveyors estimated a total population size of 440 BHS in the Escalante herd, 45 of which were estimated to reside within CARE (Bellew et al. 1995).

In 1996, CARE's central herd was established with the release of 20 BHS into the Pleasant Creek area (site # 3 in Figure 3.10.2-1) (Singer and Gudorf 1999). The following year, this herd was augmented with another 20 BHS released to the Capitol Gorge area (site # 4 in Figure 3.10.2-1).

Singer and Gudorf (1999) estimated the entire population in CARE at 150 BHS in 1997 (both the central and southern herd combined). Although the NPS developed an ambitious bi-monthly aerial and ground monitoring plan to track dispersal and population growth following these reintroductions, surveys only occurred two years post-release due to lack of funding (Sloan 2007).

During these limited studies, surveyors found that three BHS had died, and several had dispersed ~3 km (1.9 mi) to the north and south of the release sites (Singer and Gudorf 1999). A planned third release to Little Sand Flat in the northern portion of the park was cancelled because of a widespread drought that had reduced recruitment in the source herd at CANY, and because CARE's population had dispersed north of the Fremont River and south of Little Sand Flat (Sloan 2007). The central herd increased from an estimated 45 individuals in 1998 to 120 individuals by 2007 (Sloan 2007), which is the last population estimate for the central herd. The last population estimate for CARE's portion of the Escalante (southern) herd occurred in 1995 at 45 individuals.

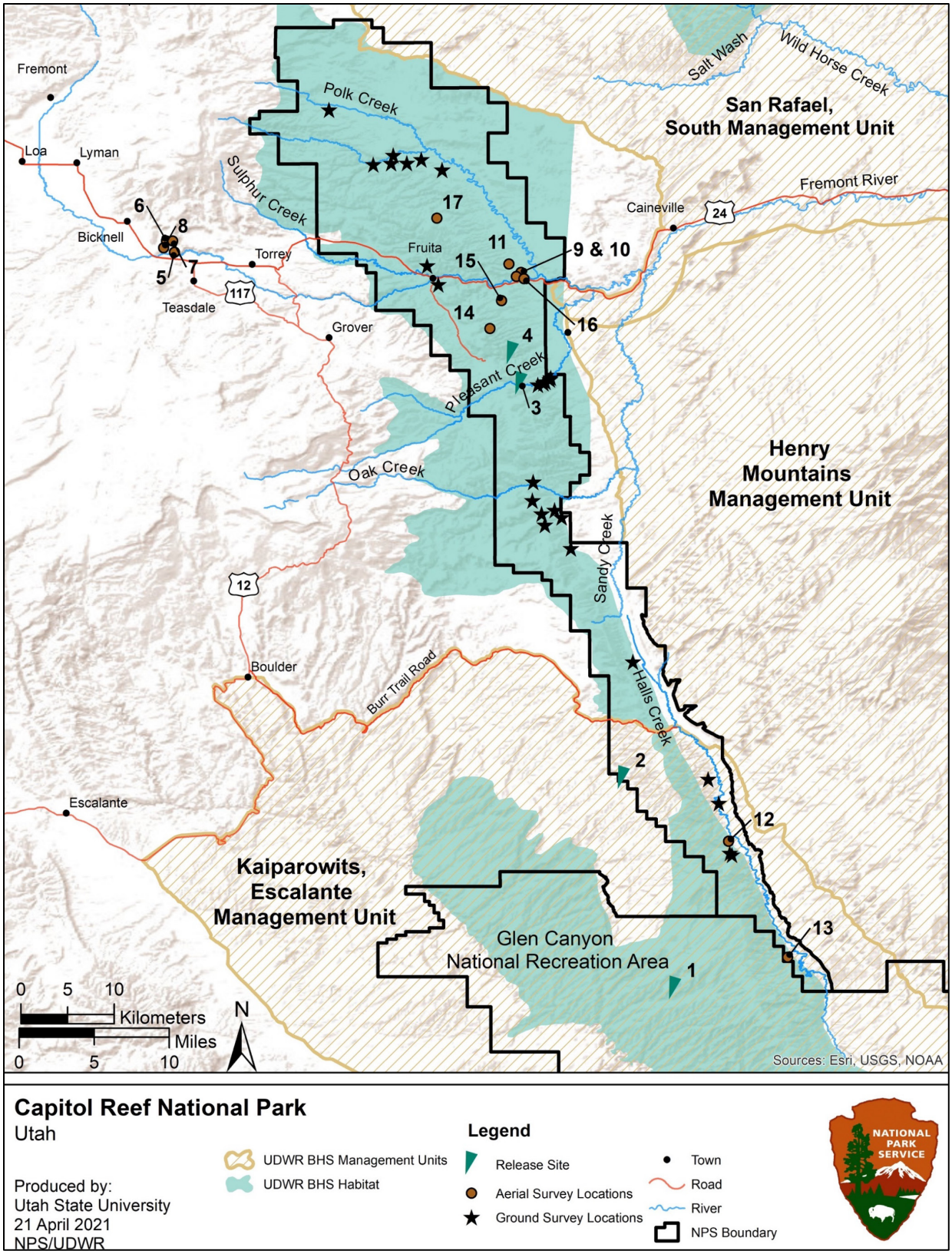


Figure 3.10.2-1. Locations of UDWR desert bighorn sheep management units, occupied habitat, release sites, and aerial and ground surveys.

Since 2007, there have been three aerial surveys in and around CARE that were conducted by UDWR (i.e., 2009, 2014, and 2017; NPS, S. Borthwick, biologist, Excel spreadsheet, 1 February 2021) and several ground surveys to document dispersal and occupancy from 2010 to 2018 (Sloan 2010, 2015, 2016, 2018). However, no population estimates were derived from these surveys.

On 13 December 2009, 15 BHS (six ewes, two lambs, seven rams) were reported at seven locations in and around CARE during an aerial survey of the UDWR Thousand Lakes Plateau management unit (NPS, S. Borthwick, biologist, Excel spreadsheet, 1 February 2021). Four of the sites where BHS were observed occurred west of CARE's boundary at Thousand Lakes Mountain just north of Highway 24 (Figure 3.10.2-1). The remaining three locations where BHS were observed occurred on Horse Mesa just north of the Fremont River near CARE's eastern boundary. In these three locations, seven BHS were reported (three ewes, one lamb, three rams). The seven rams counted during this survey ranged in age from 3.5 years to over 8.5 years old (NPS, S. Borthwick, biologist, Excel spreadsheet, 1 February 2021).

In 2014, UDWR aerial surveyors documented 20 BHS at six locations in the park (NPS, S. Borthwick, biologist, Excel spreadsheet, 1 February 2021). Ten occurred in one group of six ewes and four lambs just south of the Fremont River (Figure 3.10.2-1). An additional ram was sighted on Durfey Mesa outside the park, but no site location was reported. The three rams, at three different locations, were at least 2.5 years old. Table 3.10.2-1 summarizes BHS release and aerial survey data described above, with the map numbers corresponding to Figure 3.10.2-1. UDWR's 2017 aerial survey data were not provided.

In 2010, 2014–2015, and 2017–2018 limited ground-based surveys were conducted in the northern and central portions of the Waterpocket Fold (Sloan 2010, 2015, 2016, 2018). The primary objective of these surveys was to document range expansion and dispersal of the park's central herd (Sloan 2018). Of the five locations visited in March 2010, only two indicated the presence of BHS. These were pellets from a ram in the Navajo Knobs Trail and Longleaf Flats area. The other location was near the Cohab Trail.

During an 11-day survey (2–13 December 2014) for BHS, Sloan (2015) found that bighorn had colonized the far northern extent of the Waterpocket Fold, including the area of the proposed third release site at Little Sand Flat. Utilization of the northern Waterpocket Fold was light but consistent, and most tracks and scat indicated use by small groups of ewes and lambs or by single rams (Sloan 2015). BHS utilization in the central portion of the Waterpocket Fold, south of Oak Creek, was light and most likely consisted of lone rams or small groups of rams (Sloan 2015). Sloan (2016, 2018) found similar results during his November 2015, August 2017, and August/September 2018 surveys. Population estimates could not be derived from these surveys.

Table 3.10.2-1. Summary of BHS release and aerial survey data in and near CARE.

Map #	Area	Survey Date	Ewes	Lambs	Rams	Source
1 [1]	Moody Canyon release site	1975, 1976, 1978	17	0	6	Bellew et al. (1995)
2 [1]	Red Slide release site	January 1984/1985	21	5	5	Bellew et al. (1995)
3 [1]	Pleasant Creek release site	January 1996	15	0	5	Singer and Gudorf (1999)
4 [1]	Capitol Gorge release site	January 1997	15	0	5	Singer and Gudorf (1999)
5	Thousand Lakes Mountain	13 December 2009	2	0	1	NPS, S. Borthwick, biologist, Excel spreadsheet, 1 February 2021
6	Thousand Lakes Mountain	13 December 2009	1	1	1	NPS, S. Borthwick, biologist, Excel spreadsheet, 1 February 2021
7	Thousand Lakes Mountain	13 December 2009	0	0	1	NPS, S. Borthwick, biologist, Excel spreadsheet, 1 February 2021
8	Thousand Lakes Mountain	13 December 2009	0	0	1	NPS, S. Borthwick, biologist, Excel spreadsheet, 1 February 2021
9	Fremont River waterfall	13 December 2009	3	1	1	NPS, S. Borthwick, biologist, Excel spreadsheet, 1 February 2021
10	Fremont River waterfall	13 December 2009	0	0	1	NPS, S. Borthwick, biologist, Excel spreadsheet, 1 February 2021
11	Benches north of Fremont River waterfall	13 December 2009	0	0	1	NPS, S. Borthwick, biologist, Excel spreadsheet, 1 February 2021
12	Southern Waterpocket Fold	20 August 2014	1	1	0	UDWR unpublished data [2]
13	North of Millers Canyon	20 August 2014	1	0	0	UDWR unpublished data [2]
14	North of Capitol Gorge trail	21 August 2014	2	1	1	UDWR unpublished data [2]
15	South of Fremont River	21 August 2014	0	0	1	UDWR unpublished data [2]
16	Fremont River waterfall	21 August 2014	6	4	0	UDWR unpublished data [2]
17	South of Little Sand Flat	22 August 2014	0	0	1	UDWR unpublished data [2]
None	Durfey Mesa	21 August 2014	0	0	1	UDWR unpublished data [2]

[1] Indicates release site.

[2] UDWR data, S. Borthwick, biologist, Excel spreadsheet, 1 February 2021.

Singer and Gudorf (1999) and Norton et al. (1995) estimated that CARE provided 466 km^2 (180 mi^2) of BHS habitat, but critical habitat data, such as forage production, horizontal visibility, and water sources, were not consistently available for all areas of the park. Nevertheless, Singer and Gudorf (1999) estimated that CARE could support as many as 600 BHS based on this habitat model. This is a density of about 1.3 BHS/km^2, which is the lower end of the density range currently used by UDWR to develop population objectives for the state (UDWR 2019a). The upper end of UDWR's density range of 1.9 BHS/km^2 results in an estimated population of 885 BHS, provided the original habitat model is accurate. However, these estimates may not reflect current conditions in CARE, and an updated habitat model is warranted and planned soon (NPS, J. Ceradini, biologist, comments during manager-scientist meeting, 26 August 2021).

Population data are more current for the three UDWR BHS management units surrounding CARE; they are based on aerial counts conducted every two to three years (UDWR 2018a). The three BHS management units are the Kaiparowits, Escalante on CARE's southwestern boundary (note that this unit does not encompass the same area as Escalante herd referred to above); the San Rafael South unit on the park's northeastern boundary; and the Henry Mountains unit on the park's southeastern boundary (UDWR 2019a,b,c). Hunting is allowed in the units, and while there are no BHS hunts in CARE (NPS 2021c), hunting near its boundary is a potential stressor to park herds (NPS. J. Mack, biologist, comments during manager-scientist meeting, 30 August 2021). The Kaiparowits, Escalante unit includes the southern portion of CARE, and this, along with the San Rafael, South unit includes areas north of Lake Powell and the Colorado River in GLCA, which allows hunting (NPS 2014).

The Kaiparowits, Escalante BHS management unit currently supports an estimated 147 (last population estimate occurred in 2017) bighorn with a management goal of 400 sheep (Figure 3.10.2-2) (UDWR 2019a). The population in this unit is stable to increasing, in part because of several translocations that occurred in the years preceding the last population estimate. A total of 120 sheep were transplanted to this unit in 2013 and 2014 (178 total since 1975) (Figure 3.10.2-2). All transplanted sheep were sourced from other populations in Utah, except for transplants in 2013 and 2014, which were sourced from Nevada (UDWR 2019a). From 2009 to 2020, 36 rams have been harvested from this unit, with an average of 3 rams/year (UDWR 2018b, 2019d, 2020). Because the Kaiparowits, Escalante BHS population is well below its objective, the UDWR implemented an unlimited mountain lion hunt in 2014 (UDWR 2019a). Since 2014, an average of 1.2 lions have been harvested per year in this unit (UDWR 2019a).

UDWR notes that there is substantial habitat connectivity throughout the Kaiparowits, Escalante unit, including the portion within CARE (UDWR 2019a). BHS in the unit have tested positive for *M. ovipneumoniae,* but no substantial die-offs have been reported to date (UDWR 2019a). However, the population does not appear to be increasing, so it's likely that disease is a factor. Because of recent disease detection, no further transplants are planned for this unit until a disease profile of source populations and resident populations is complete (UDWR 2018a).

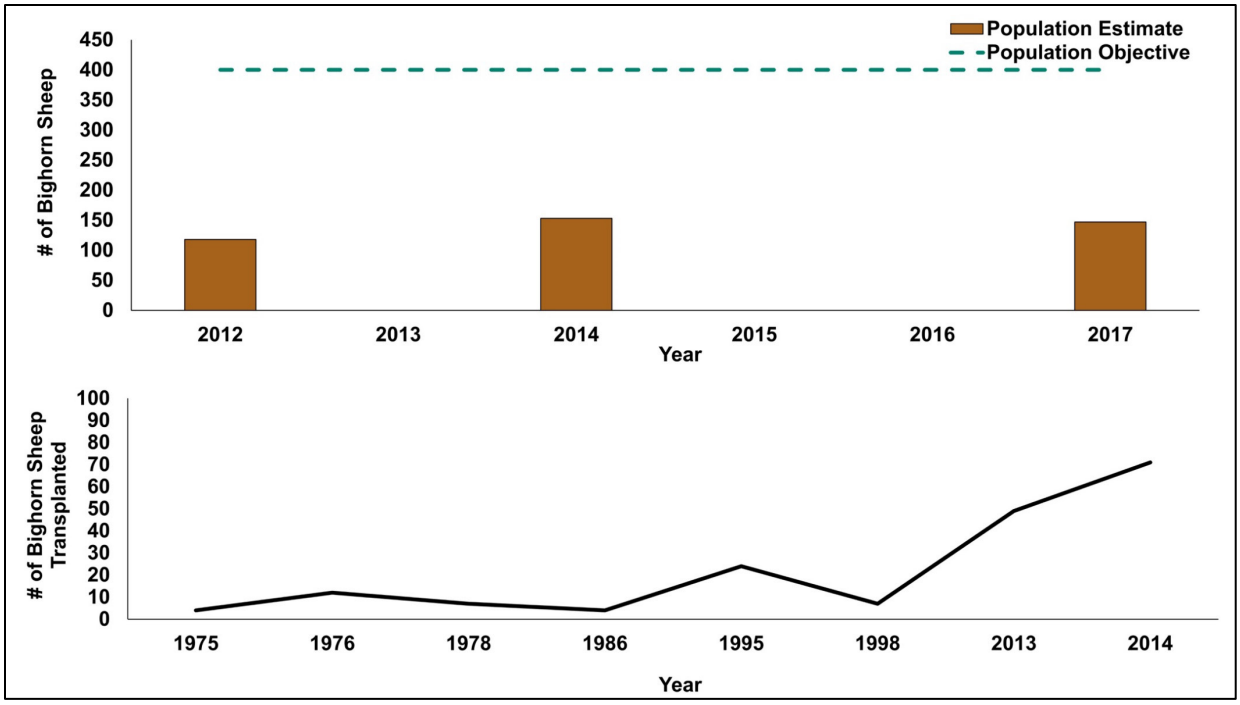


Figure 3.10.2-2. Bighorn sheep population estimate compared to the population objective (top) and the number of transplants for the Kaiparowits, Escalante management unit (bottom). Note the different scales on the x and y axes.

UDWR's objective for the San Rafael, South BHS management unit is a population of 500 bighorn, with the most recent (2019) estimate at 222 BHS (Figure 3.10.2-3) (UDWR 2019b). BHS in the San Rafael, South unit have declined 39% between 2015 and 2018 (UDWR 2019b). From 1983 to 1998, 50 BHS were transplanted to San Rafael, South with no translocations since 1998 (UDWR 2018a). All sheep were sourced from other populations in Utah, including CANY. Several BHS in the adjacent units (San Rafael, North and San Rafael, Dirty Devil) have tested positive for *M. ovipneumoniae*. A disease assessment was scheduled for the winter of 2019/2020 to determine if pneumonia was a contributing factor in the San Rafael, South population decline (UDWR 2019b). Although the results of that assessment were unavailable to include in this gap analysis, disease is present and UDWR staff assumes it is contributing to the declines and lack of population growth in the herd (UDWR, Riley Peck, BHS lead biologist, comment received by N. Galloway and sent to T. Cook on 2 June 2021).

According to UDWR, the closest domestic sheep to occupied BHS habitat in the San Rafael, South management unit are in South Wolf Hollow and Rock Canyon allotments. There are also active allotments through which sheep are trailed from Cleveland to Castle Dale through the Cleveland Winter allotment, the Red Seeps allotment, and the Buffalo and Hadden Hills pastures of the Buckhorn allotment (UDWR 2019b). Farm flocks are also on private lands along State Route 10 (UDWR 2019b).

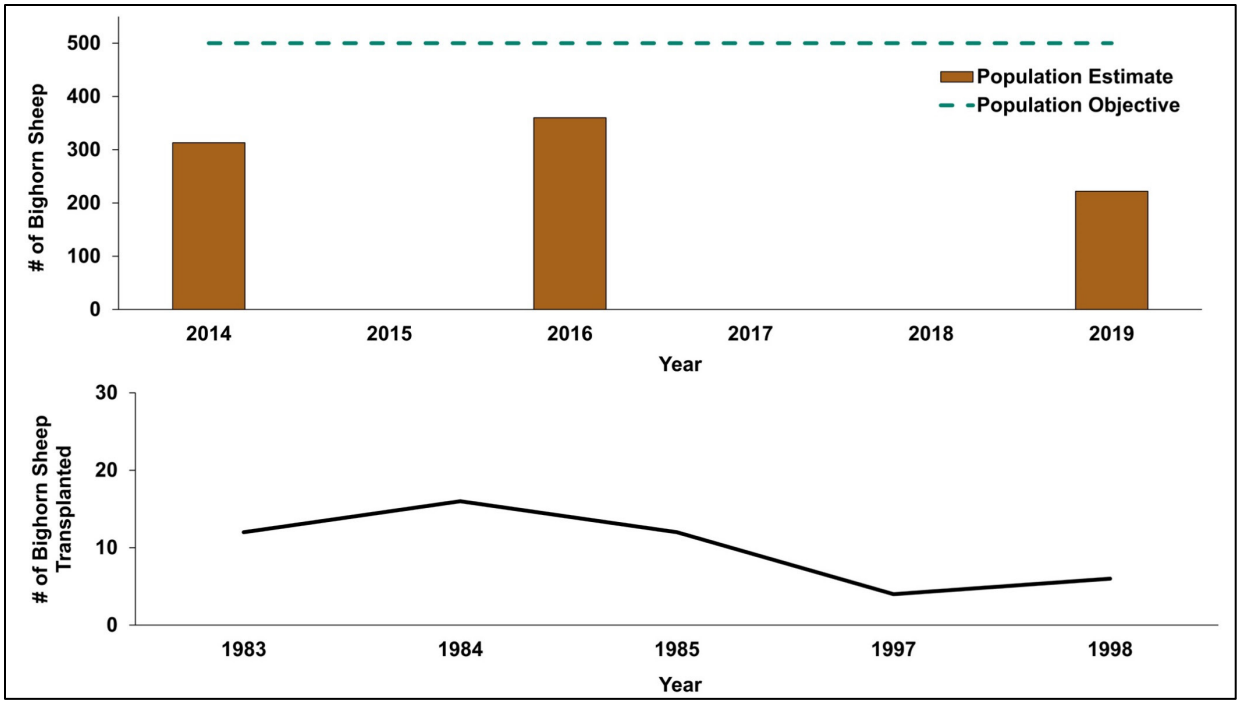


Figure 3.10.2-3. Bighorn sheep population estimate compared to the population objective (top) and the number of transplants for the San Rafael, South management unit (bottom). Note the different scales on the x and y axes.

Predation by mountain lions may also contribute to declines in BHS in San Rafael, South. One study found that 50% of collared sheep in this unit were killed by mountain lions (UDWR 2019b). This is similar to the results found in CARE following the mid-1990s release of 40 BHS. Of the 10 collared sheep that died before their radio battery failed, 40% were killed by mountain lions (Sloan 2007). Because of high predation in San Rafael, South, this unit is designated as a BHS protection area with a liberal mountain lion harvest quota and year-round hunting season (UDWR 2019b). An annual average of seven mountain lions were harvested in the larger management unit that includes San Rafael, North and San Rafael, Dirty Devil from 2015 to 2017 (UDWR 2019b), but it's unknown whether this influenced the BHS population there (UDWR, Riley Peck, BHS lead biologist, comment received by N. Galloway and sent to T. Cook on 2 June 2021). From 2009 to 2020, 92 rams have been harvested from San Rafael, South, with an average of 7–8 rams/year (UDWR 2018b; UDWR 2019d; UDWR 2020).

The most recent population estimate for the Henry Mountains BHS management unit is 153 bighorn (2016), with a population objective of 200 (Figure 3.10.2-4) (UDWR 2019c). The bighorn population in the unit is stable to increasing. Thirty-nine BHS were transplanted to this unit in 1985, but no transplants have occurred since (UDWR 2018a). All BHS were sourced from two populations in Utah (CANY and Red Canyon/White Canyon) (UDWR 2018a). BHS predation by mountain lions was cited as a potential limiting factor as their preferred prey (mule deer [*Odocoileus hemionus*]) decline (UDWR 2019c). From 2009 to 2020, 28 rams have been harvested from this unit, with an average of 2–3 rams/year (UDWR 2018b; UDWR 2019d; UDWR 2020).

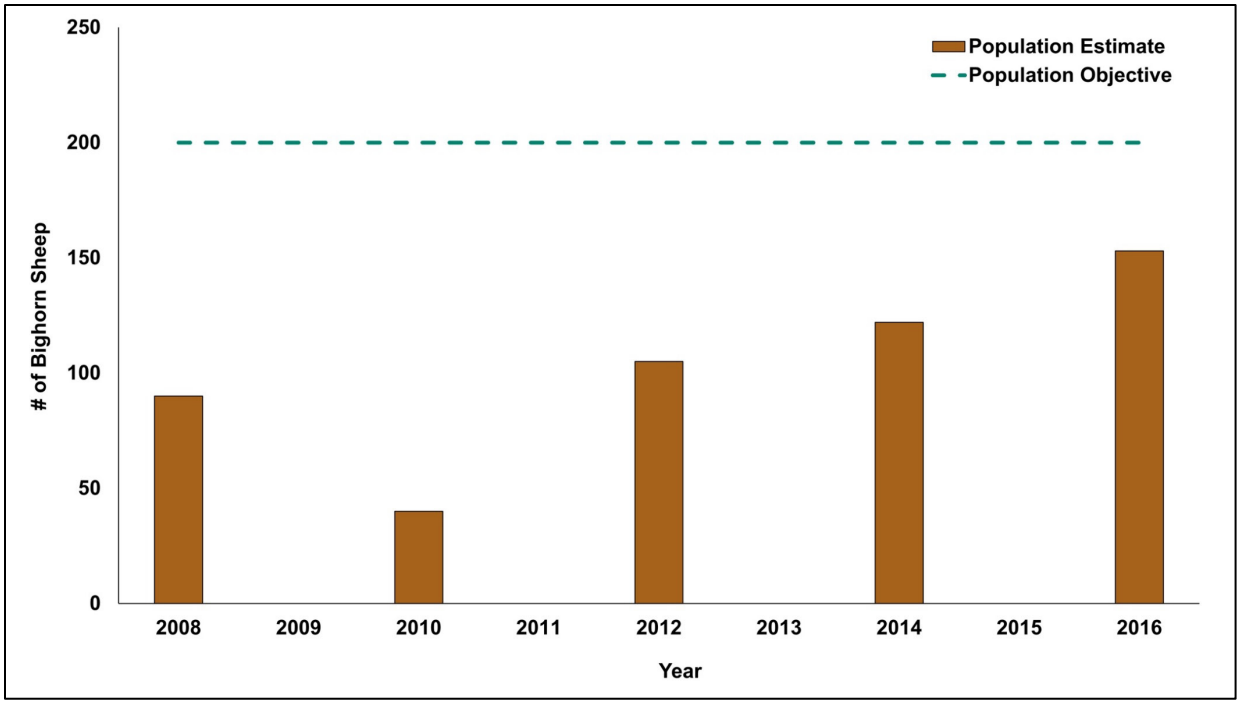


Figure 3.10.2-4. Bighorn sheep population estimate compared to the population objective for the Henry Mountains management unit.

In 2017, 15 female and four male BHS tested positive for *M. ovipneumoniae* at Hillers (4 BHS), North Wash (1 BHS), Peshliki (4 BHS), and Trachyte (10 BHS) in the Henry Mountains unit (UDWR 2019c); however, the area bordering CARE is currently unoccupied by BHS. Hobby farms along State Route 276 pose the greatest disease risk to BHS in this management unit (UDWR 2019c). One BLM domestic sheep allotment (Trachyte) poses a challenge to separation because it is directly adjacent to BHS habitat. While cattle currently graze the allotment, sheep are also allowed under a previous BLM management plan (UDWR 2019c).



Desert bighorn sheep along Oak Creek in CARE. Image Credit: NPS.

The USFS completed a Risk of Contact assessment for domestic and BHS in the national forests of Utah based on models developed by Carpenter et al. (2014), which were based on O'Brien et al. (2014). The analysis did not indicate any conflicts between domestic and BHS in the Fishlake or Dixie NFs (USFS 2016). There are, however, privately owned farm flocks near CARE (Figure 3.10.2-5).

Figure 3.10.2-5 presents data for the purpose of identifying areas of potential overlap between BHS occupied habitat and domestic sheep and goat allotments on BLM and USFS lands. Superscript one in the map denotes areas where the BLM issued grazing bills, which are issued on an annual basis, and allowed domestic sheep or goat use during the 2017 grazing fee year (3/1/17–2/28/18). Superscript two in the map denotes areas where the BLM authorized domestic sheep or goat use within all or part of the allotment (current as of 2/28/19). The GIS data were derived from the USFS, BLM, and the Western Association of Fish and Wildlife Agencies Wild Sheep Working Group (NPS, A. Stoneburner, GIS specialist, email correspondence, 19 July 2021).

Private flocks of domestic sheep occur near Grover, Utah—an 11–13 km (7–8 mi) distance from CARE's central herd. There are also domestic sheep in Bicknell, Utah which is about 21 km (13 mi) from BHS habitat along CARE's western boundary (Woolever, *In Draft*). A domestic goat was found in Grand Wash (central BHS herd) in 2017, which was removed by the NPS (Woolever, *In Draft*). Mesa Market in Caineville, Utah has goats, which are over 8 km (5 mi) from the park's BHS populations and about 16 km (10 mi) from the park's east boundary (NPS, S. Borthwick, biologist, comments to draft evaluation, 13 May 2021). Distances to allotments are misleading because there are BHS in habitat outside the park near allotments, and the habitat is highly connected. BHS moves freely in and out of CARE (Woolever Consulting, M. Woolever, biologist, phone call, 26 June 2021 with Lisa Baril), even though much of CARE's boundary is fenced or in rugged terrain, creating natural barriers to movement (Woolever, *In Draft*).

The herd near Bicknell, Utah, located approximately 13 mi (21 mi) west of CARE, was culled in 2014 because of interactions with domestic sheep (Woolever, *In Draft*). In 2014, Sloan (2015) reported a coughing ewe observed in the southern Waterpocket Fold (Escalante herd). The ewe was with eight other ewes, one juvenile, and four rams. This group was in the drainage between Muley Twist and Brimhall Bridge; besides the coughing ewe no other health problems were apparent (NPS, S. Borthwick, biologist, comments to draft evaluation, 13 May 2021). In 2018, pneumonia was identified in two sheep: an 8–10-year-old ram from the southern herd and a lamb from the central herd (Woolever, *In Draft*). The lamb died before being culled (Sloan 2018), but the ram was collected by UDWR. Other pathogens, in addition to *M. ovipneumoniae*, were also detected in at least one sheep listed in Table 3.10.2-2. These include *Bibersteini trehalosi*, *Trueperalla pyogenes*, and *Mannheimia haemolytica,* which also contribute to respiratory disease in BHS (Besser et al. 2012; Rzewuska et al. 2019).

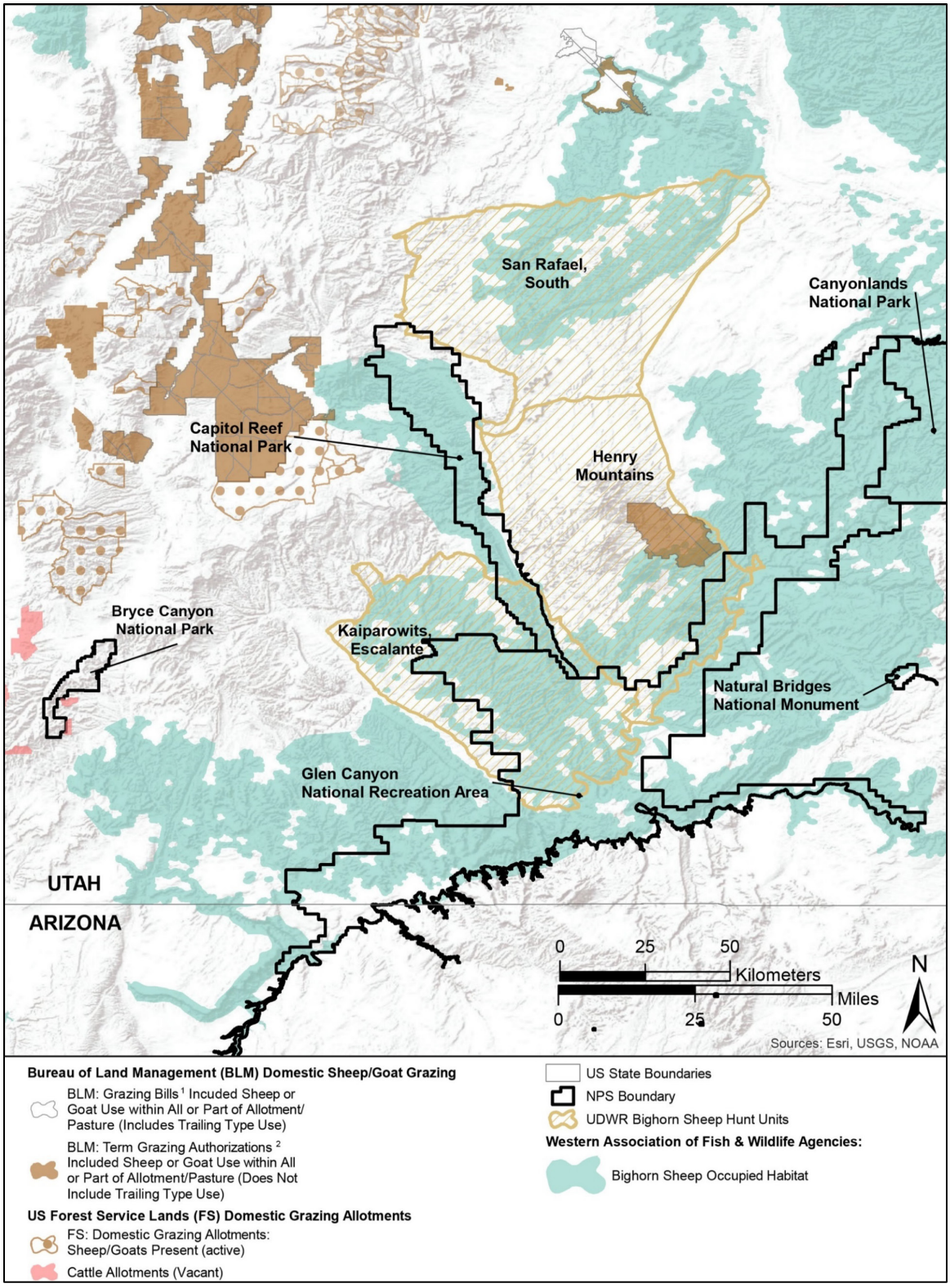


Figure 3.10.2-5. Locations of domestic sheep, goat, and cattle allotments surrounding CARE. Please refer to text for disclaimers denoted by superscripts in legend. Figure Credit: NPS / ALEX STONEBURNER.

Table 3.10.2-2. Disease testing summary in recently euthanized desert bighorn sheep in CARE.

Date of Sample Collection	Type of Sample Collection	Location	Age/Sex	*Mycoplasma ovipneumoniae*	Notes
26 February 2018	Nasal swab	Lower Muley Twist	8–10-year-old ram	Positive	*Bibersteini trehalosi* and *Trueperella pyogenes* were detected. After this sheep's death, other sheep were observed coughing on the Post Cutoff trail.
9 November 2018	Nasal swab	Cohab Canyon Trail	4-year-old ram	Not Detected	Ram was paralyzed in hind legs but appeared otherwise healthy. *Mannheimia haemolytica* detected, but *Pasteurella leukotoxin* was not detected.
25 August 2018	Nasal swab	Pleasant Creek	6-month-old ram	Positive	Severe cough observed in lamb on 18 August 2018. Other lambs in group appeared healthy, but several were also coughing deeply. A juvenile ewe with a tumor on the left side of her neck was also observed. The lamb was found dead 24 August 2018.

3.10.3. Discussion

Table 3.10.3-1 presents two proposed indicators and three measures to assess the condition of CARE BHS in the future. An updated and accurate habitat map would allow park managers to determine habitat connectivity within and around CARE and to estimate the BHS population size. Ground surveys may be more feasible than aerial surveys in CARE and may include the collection of fecal samples for genetics. Stationary surveys may also be conducted from good vantage points using spotting scopes to estimate population size. We did not suggest a range of ewe to lamb ratios because these reference criteria vary widely (UDWR 2018b). Pneumonia is already present in CARE BHS and has resulted in the death of at least two animals in recent years. Fortunately, no significant die-offs have been reported to date, but that does not mean they haven't occurred. Much of CARE is rugged and difficult to access, with limited surveys in the more remote areas where BHS are likely to occur.

Table 3.10.3-1. Proposed study details for desert bighorn sheep.

Indicator of Condition	Measure	Reference Criteria for Measure
Population Size and Structure	Population size and distribution	BHS are well distributed throughout the park in appropriate habitat such that the population (with movement in and out of the park) is sustainable.
	Lambs to Ewe and Ram to Ewe ratios	Multiple age classes that demonstrate recruitment in breeding age adults and presence of lambs. Ratios vary significantly throughout their range.
Pathogen Transmission and Prevalence	Presence / Absence and effects of *Mycoplasma ovipneumonia*	*Mycoplasma ovipneumonia* does not cause large die-offs leading to population declines. Herds can cope with disease in the population.

High susceptibility of BHS to pneumonia transmission from domestic sheep and goats presents a significant management problem. This is because maintaining healthy BHS populations depends on gene flow through connected habitat, but connected habitat may serve as a pathway for disease transmission between herds, especially if corridors pass through domestic sheep and goat grazing allotments or private ranches (Cassirer et al. 2018). Singer et al. (2001) recommended ≥23 km (14.3 mi) of separation between BHS and domestic sheep, but the current model estimates 35 km (21.7 mi) (Woolever Consulting, M. Woolever, biologist, comments to assessment, 29 April 2021).

Although ewe/lamb groups tend to range short distances, rams occasionally travel long distances in exploratory movements to and from their core herd home ranges (Carpenter et al. 2014). Foraying rams/ewes that contract pneumonia are likely to transmit the disease to individuals within their core herd when they return; the infected herd member may spread disease to other herds where ranges overlap (Woolever Consulting, M. Woolever, biologist, comments to assessment, 29 April 2021).

In a spatial risk assessment of BHS extirpation through contact with grazing domestic sheep, Carpenter et al. (2014) found that half of all BHS forays in the Payette NF in Idaho reached 10 km (6.2 mi), 25% reached at least 16 km (9.9 mi), and one ram reached 35 km (21.7 mi) from the center

of its home range. Private flocks in Grover, Bicknell, and Caineville, Utah are well within these distances to CARE. However, straight-line distances do not necessarily demonstrate connectivity. Nevertheless, these distances serve as a starting point for assessing the actual connectivity between wild BHS herds to one another and to domestic sheep and goats.

A study of genetic diversity and vulnerability of BHS to climate change in 62 national parks revealed that CARE's BHS are most genetically similar to those in ARCH, CANY, and GLCA (Creech et al. 2020), which is not surprising since BHS from CANY were translocated to both CARE and ARCH. Compared to all 62 parks, CARE was rated as intermediate in terms of genetic diversity and climate vulnerability of its BHS population (Creech et al. 2020). Translocating BHS not only reintroduces bighorn to their former ranges, but also increases genetic diversity. Other threats to CARE's BHS include increased backcountry use, Tar Sands development, hunting near the boundary, mountain lion predation, non-native invasive plants, and water availability. Additional stressors include collisions with vehicles and human encounters (NPS. J. Mack, biologist, comments during manager-scientist meeting, 30 August 2021).

In summary, none of UDWR's BHS management units adjacent to CARE meet the population objectives despite decades of transplants. While this doesn't necessarily reflect a reduced population in CARE, the evidence suggests that the size is far less than 600 BHS. Disease, confirmed as present in CARE, is a likely factor, but there may be other factors. To address the lack of standardized surveys of BHS in CARE, NPS and Utah Valley University researchers recently completed the fieldwork for a camera-trap survey and fecal pellet sampling study, using a standard occupancy framework. The objectives of the project are to 1) determine the mechanisms behind patterns of BHS habitat use on the landscape, 2) estimate the overall probability of use in the park, 3) create a habitat use probability map for the park based on occupancy models, and 4) estimate indices of population connectivity (Ceradini et al. 2021). The information from this effort will help inform many of the data gaps regarding BHS in CARE.

3.11. Fishes (Condition Assessment)

3.11.1. Background & Importance

Five native fish species in CARE include bluehead sucker (*Catostomus discobolus*), flannelmouth sucker (*C. latipinnis*), and roundtail chub (*Gila robusta*), which are species of special conservation status in Utah (UDNR 2006), and the speckled dace (*Rhinichthys osculus*) and mottled sculpin (*Cottus bairdi*). Non-native species include redside shiner (*Richardsonius balteatus*), leatherside chub (*Snyderichthys copei*), and rainbow trout (*Oncorhynchus mykiss*).

The Fremont River is the principal perennial stream in CARE, but other perennial streams include Sulphur, Pleasant, Oak, Polk, and Halls creeks. Other than for the Fremont River and, to a lesser extent, Pleasant Creek, there is little information about the abundance and distribution of fish in park waters. Since CARE contains only a portion of these perennial streams, they are heavily influenced by upstream activities (NPS 2018a). In November 1991, an entire barrel of rotenone was accidentally released in the Fremont River upstream of the park (Hepworth et al. 1993). The UDWR's intention was to remove trout infected with whirling disease, which is caused by the invasive parasite *Myxobolus cerebralis*. Large quantities of potassium permanganate were then released into the river to counteract the rotenone, which resulted in a widespread fish and invertebrate kill (Hepworth et al. 1993). Follow-up sampling a year after the spill showed abundant native fish populations within the park, which suggested that fish had recovered from the event (Hepworth et al. 1993). Although this is an extreme example, other activities occurring upstream (e.g., agriculture, ranching, and vegetation treatments) influence CARE's water quality downstream.



Speckled dace. Image Credit: USFWS.

3.11.2. Study Framework

This condition assessment includes the Fremont River, as well as Sulphur, Pleasant, Oak, Polk, and Halls creeks when data were available. We used four indicators and eight measures to evaluate the condition of fish species in CARE (Table 3.11.2-1). The biological community indicator includes measures of native and non-native fish occurrences and native fish recruitment. We also included an indicator of habitat quality (i.e., the distribution and amount of various bedform substrates and hydraulic features) and two measures of water quality (temperature and dissolved oxygen). Because water quality is also included in the riparian assessment, we focused on only those measures most

likely to affect fish. We also included an indicator of contaminants, using measures of mercury and contaminants of emerging concern (CEC). CECs include personal care products, pharmaceuticals, pesticides, and wastewater indicators (Weissinger et al. 2018b). Data for most, if not all, measures were available for the Fremont River. Data for some measures were also available for Pleasant Creek, but there were few data for the remaining streams, particularly regarding fish assemblages.

Table 3.11.2-1. Study details for the fishes condition assessment.

Indicator of Condition	Measure	Reference Criteria for Measure
Biological Community	Native fish occurrence	All native species are consistently present in each of the surveys conducted.
	Recruitment	Length-frequency histograms indicate a stable or growing native population with multiple age classes represented.
	Non-native fish occurrence	Non-native species are absent or limited in distribution and abundance.
Habitat Quality	Bedform (e.g., cobble, gravel, sand) and hydraulic features (e.g., riffle, run)	The distribution and amount of bedform and hydraulic features indicate suitable habitat to support the full suite of native fish species.
Water Quality	Temperature	Doesn't exceed the standards optimal for aquatic life (27 °C (81 °F) for warm and 20 °C (68 °F) for cold water), depending on stream sampled. Percentage of exceedances suggest acute rather than chronic issues.
	Dissolved oxygen	Doesn't exceed the standards optimal for aquatic life (5.5 mg/L for warm water and 6.5 mg/L for cold water), depending on stream sampled. Percentage of exceedances suggest acute rather than chronic issues.
Contaminants	Mercury	Concentrations indicate low potential risk to reproduction and development (i.e., <300 ppb in dragonfly larvae). Wet mercury deposition is low or very low (<6 $\mu g/m^2/yr$) and predicted methylmercury concentration is low or very low (<0.053 ng/L).
	Contaminants of emerging concern (CECs)	For any one pollutant, no more than one occurrence is detected.

Numerical criteria for recruitment were not included since the suite of native species differ in their growth and development patterns. Similarly, fish rely on different habitat characteristics depending on life stage and species (Bezzerides and Bestgen 2002; Bower et al. 2008). For temperature and dissolved oxygen, we used standards developed by the UDWQ (2020b) for cold water (Fremont River, and Polk, Sulphur, Pleasant, and Oak creeks) and warm water (Halls Creek) aquatic life. For the mercury reference criteria, we used the impairment benchmarks for fish outlined by the USGS as part of the dragonfly mercury project (Eagles-Smith et al. 2020), as well as reference criteria for wet mercury deposition and predicted methylmercury concentration developed by the NPS ARD (2021a). There are no reference criteria for most CECs; therefore, we used a near-zero tolerance based on

information published in the Fremont River watershed water quality management plan, which describes toxic parameter targets for full support of agricultural beneficial use (UDWQ 2002). The condition rating statements (Appendix B, Table B-6) for the remaining three indicators were based on the Office of National Marine Sanctuaries (2020) marine sanctuary criteria for living resources, water quality, and habitat. Measures with greater potential to influence indicator condition were given more weight in the overall condition rating statements.

3.11.3. Data & Methods

The UDWR surveyed the fish community at approximately 15 stations along the Fremont River (Figure 3.11.3-1) in 1992 (Hepworth et al. 1993), 2005–2006 (Doyle et al. 2006a; Fridell et al. 2005), and biennially from 2010 to 2018 (Dobbs and Reynolds 2010; Trujillo 2012, 2014; Woodhouse 2016, 2018). Not every station was surveyed in every year that surveys took place, and there were some differences in survey locations between years, but in general, surveys occurred from just west of Highway 12 (west of CARE's boundary) to the confluence of Pleasant Creek, east of the park. In 2006–2007 and 2021, UDWR also surveyed several stations along Pleasant Creek from just west of CARE's boundary to the confluence with the Fremont River (Doyle et al. 2006b; Golden and Black 2007). UDWR also surveyed Sulphur and Halls creeks in 2021.

The UDWR surveys consisted of depletion seining, whereby most (last capture <10% of highest capture) fishes were captured at a site within a station before being returned to the stream. Surveyors also recorded fish length, to derive recruitment information, and habitat composition along the length of the river surveyed (the latter measure for the Fremont River only).

Additional surveys were conducted along the Fremont River in 2000, 2005–2007, and 2009, and in Pleasant Creek in 2009 by Mansfield University (Kirby and McAllister 2005, 2007, 2009; Schwarzbach 2000, 2001). In 1993, CARE staff and a biologist from the USFWS Denver regional office surveyed parts of the Fremont River, Pleasant Creek, and Sulphur Creek (Borthwick 1993).

The NPS NCPN collected temperature and dissolved oxygen data (among other parameters) from six locations on five streams in CARE (two locations on Sulphur Creek, and one each on Pleasant, Oak, and Halls creeks, and the Fremont River) (Hackbarth and Weissinger 2020). Samples were collected during the water year (1 October–30 September) in four sampling periods from 2005 to 2018. Not every site/stream was sampled during each survey period.

From 2005 to 2007, Sulphur, Pleasant, and Oak creeks were not sampled (Thoma et al. 2008). Halls Creek was not sampled during the 2009 to 2012 survey period (Hackbarth and Weissinger 2013). And the Fremont River was not sampled during the 2012 to 2015 (Hackbarth and Weissinger 2016) and 2015 to 2018 (Hackbarth and Weissinger 2020) survey periods. Data were reported as percentage of exceedances for each of the four time periods. We also reported 2018/2020 UDWQ impairment data for the perennial streams considered in this assessment (UDWQ 2020b). Lastly, we reported temperature and dissolved oxygen data collected at Pleasant Creek (temperature only) and the Fremont River from the mid-1970s to early 1990s (NPS 1994b).

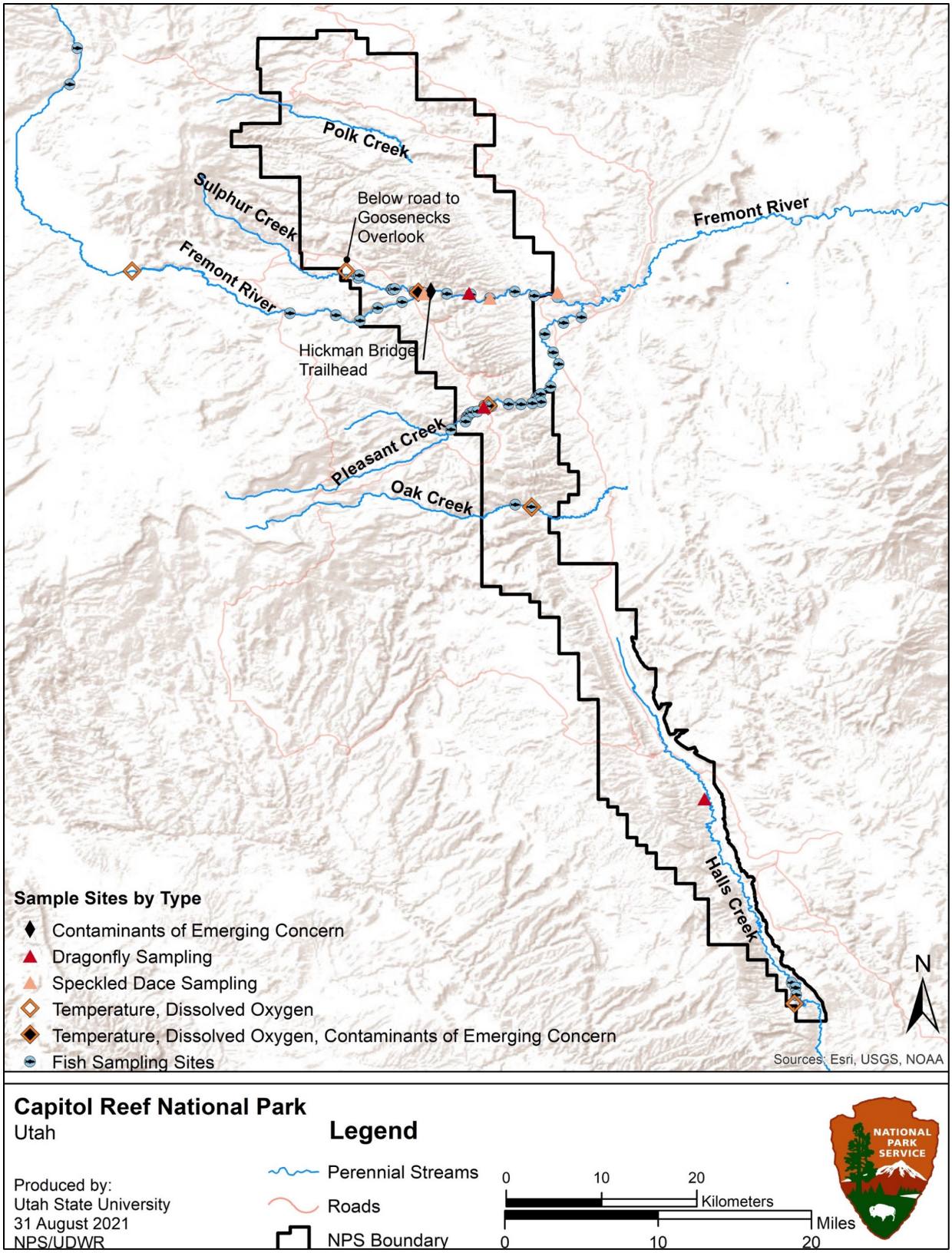


Figure 3.11.3-1. Fish and water quality sampling sites in and around CARE.

During 2012 to 2015, the NCPN tested water samples from the Fremont River and Sulphur Creek. Testing included a total of 253 CECs (Weissinger et al. 2018b). At the Fremont River monitoring site, water samples were tested for 140 to 253 CECs per year. Although data were collected in 2010, they were not included in this report or in Weissinger et al. (2018b) because: 1) there were no quality control samples collected that year; 2) there was a higher frequency and concentration of detections in 2010 that was not corroborated by subsequent sampling; and 3) when quality control samples were added in subsequent years, Weissinger et al. (2018b) found frequent blank detections that required a careful evaluation to determine whether the source water detection was real or contamination (NPS, R. Weissinger, aquatic ecologist, e-mail message, 24 March 2021). At the Sulphur Creek site, water samples were tested for 253 CECs in 2014 and 207 CECs in 2015 (Weissinger et al. 2018b).

The NPS ARD assesses mercury condition using three measures of mercury amounts entering an ecosystem: 1) wet mercury deposition measurements, 2) landscape sensitivity to mercury methylation, and 3) risk to fish and wildlife (NPS ARD 2021a). A major contributor of mercury to remote inland water bodies is atmospheric deposition. Wet deposition transfers atmospheric constituents to the Earth's surface in precipitation (NPS ARD 2021a). Mercury ultimately enters water bodies via surface run-off. Atmospheric inputs of elemental or inorganic mercury must be methylated before it is biologically available and able to accumulate in food chains that can affect both wildlife and human health (NPS ARD 2021a).

For this assessment, mercury deposition was derived by extracting the maximum value within CARE boundaries from a deposition surface that was generated as a product of two surfaces: annual mercury estimated concentration gradients from the National Atmospheric Deposition Program and modeled 30-year annual precipitation norms from the PRISM Climate Group (2015–2017) (NPS ARD, K. Taylor, data analyst, contribution to draft evaluation, 17 August 2021). Conditions of predicted methylmercury concentration (nanograms per liter [ng/L]) in surface water were derived from modeled data that predict surface water methylmercury concentrations for hydrologic units throughout the U.S. (NPS, K. Taylor, data analyst, contribution to draft evaluation, 17 August 2021). The model is based on relevant water quality characteristics (i.e., pH, sulfate, and total organic carbon) and wetland abundance (USGS 2015). The predicted methylmercury concentration at a park is the highest value derived from the hydrologic units that intersect the park (NPS, K. Taylor, data analyst, contribution to draft evaluation, 17 August 2021).

The NPS and the USGS tested 45 speckled dace for mercury at three locations along the Fremont River during 2012 (Eagles-Smith et al. 2014). And in 2017 and 2018, the NPS and USGS sampled dragonfly larvae for mercury at three locations: Fremont River, Pleasant Creek, and a wetland near Halls Creek (Eagles-Smith et al. 2020; USGS 2020b). We also reviewed CARE's baseline water quality report for mercury sampling in the Fremont River (NPS 1994b).

3.11.4. Results & Discussion

In the Fremont River, native fish represented an average of 81.9% of the annual capture from 1992 to 2018 (Figure 3.11.4-1). This excludes data from 1993 (abundance was not reported for each species) and 2012 (65% of fish were fry and could not be identified to species). The mean over the last five sampling periods conducted by UDWR (excluding 2012) was 78.1%, which suggests a decline in

abundance, although this could be due to differences in effort/sampling or other natural factors (e.g., floods). During 2018, non-native fish captures were highest since regular monitoring by UDWR began in 2010.

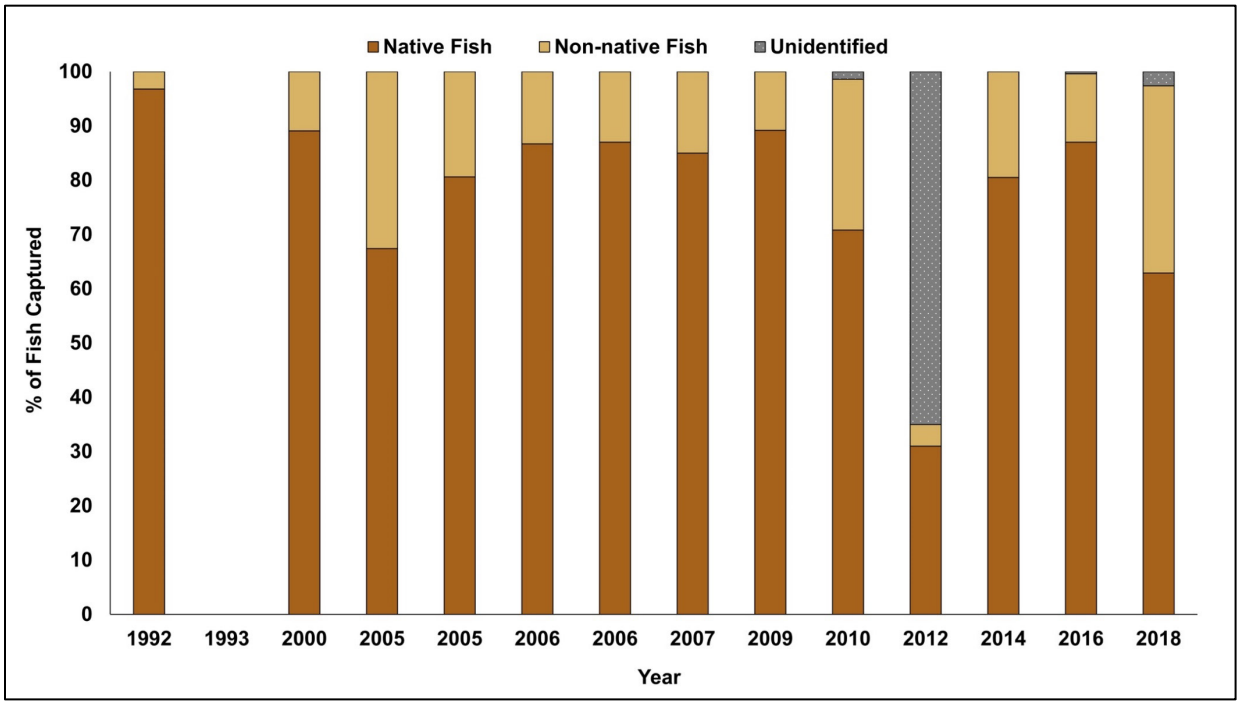


Figure 3.11.4-1. Percentage of native versus non-native fish captured in the Fremont River from 1992 to 2018. A total of 13 surveys occurred in the Fremont River, with two separate surveys occurring in 2005 and 2006 each.

Overall, species captured included four native and seven non-native species (Figure 3.11.4-2). Speckled dace was the most common native species, followed by flannelmouth sucker, and bluehead sucker. Mottled sculpin was less abundant but present in all survey years except for 1993, although this may be due to sampling effort. Mottled sculpins are naturally uncommon and are also difficult to capture, which has resulted in low estimated abundances in the park (Hepworth et al. 1993). However, during UDWR surveys in 2006, mottled sculpins were abundant, which may be because sampling occurred upstream of Fruita, which is considered better habitat (NPS, S. Borthwick, biologist, comments to draft evaluation, 27 April 2021). Roundtail chub was absent in all surveys.

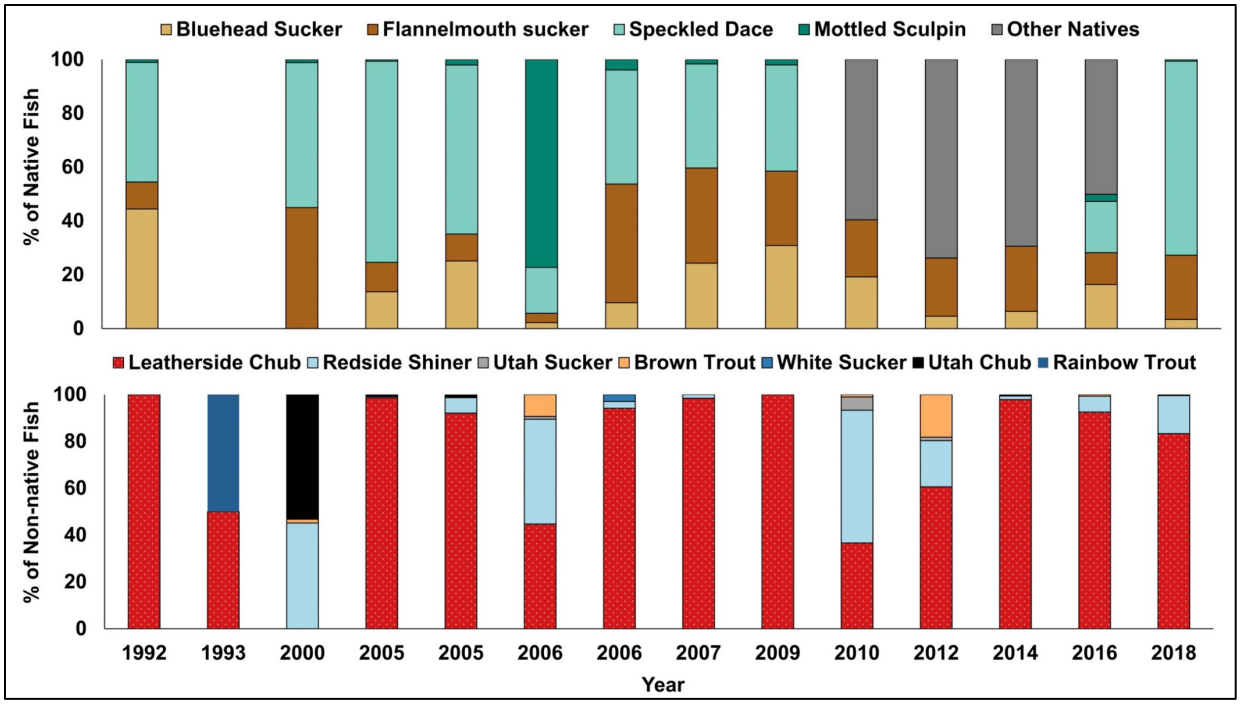


Figure 3.11.4-2. Percentage of native fish by species (top) and non-native fish by species (bottom) captured in the Fremont River from 1992 to 2018.

Leatherside chub (*Lepidomeda aliciae*) was the most abundant non-native species followed by redside shiner. Utah sucker (*Catostomus ardens*) and brown trout (*Salmo trutta*) captures were highly variable between surveys, ranging from none in several years to ~12 in other years.

An unknown sucker (*Catostomus* sp.), Utah chub (*Gilia atraria*), and rainbow trout were also reported but were very rare, with no captures in most years, including the most recent sampling effort (2010–2018). UDWR refers to the white sucker (*Catostomus commersonii*), which is apparently not present in CARE, so we listed this species as an unknown sucker (NPS, M. Trammell, fisheries biologist, comments to draft assessment, 17 May 2021). Notably, the 2000 sampling results show that no leatherside chubs were captured, but that 33 Utah chubs were captured. In most years, few, if any, Utah chubs were present. Although there is no way to know, it's possible that leatherside chubs were misidentified as Utah chubs (NPS, S. Borthwick, comments to draft evaluation, 27 April 2021).

During the 2018 sampling of fish in the Fremont River, UDWR concluded that both bluehead and flannelmouth suckers were successfully reproducing given the high number of fry (Woodhouse 2018). Additionally, fishes were in the 90–120 mm (3.5–4.7 in) length range, indicating successful recruitment of both species from previous years. Multiple adult age classes suggested that fish of reproductive age were present (Woodhouse 2018). The distribution of speckled dace also indicated successful recruitment in the Fremont River. The majority of leatherside chub and redside shiner captures were young of the year, and there were multiple adult age classes of both species, which indicated successful reproduction and recruitment for these non-native species as well. There were

too few Utah suckers in 2018 (n = 5) to determine recruitment, but even this small number indicates persistence (Woodhouse 2018).

Along the Fremont River, hydraulic features consisted of mostly runs, with some pools and riffles (Figure 3.11.4-3). Backwater habitat was rare. Cobble, followed by gravel, and then boulders, represented the majority of bedform substrates in most biennial years from 2010 to 2018. While these three bedform classes remained relatively stable, the proportion of sand was more variable.

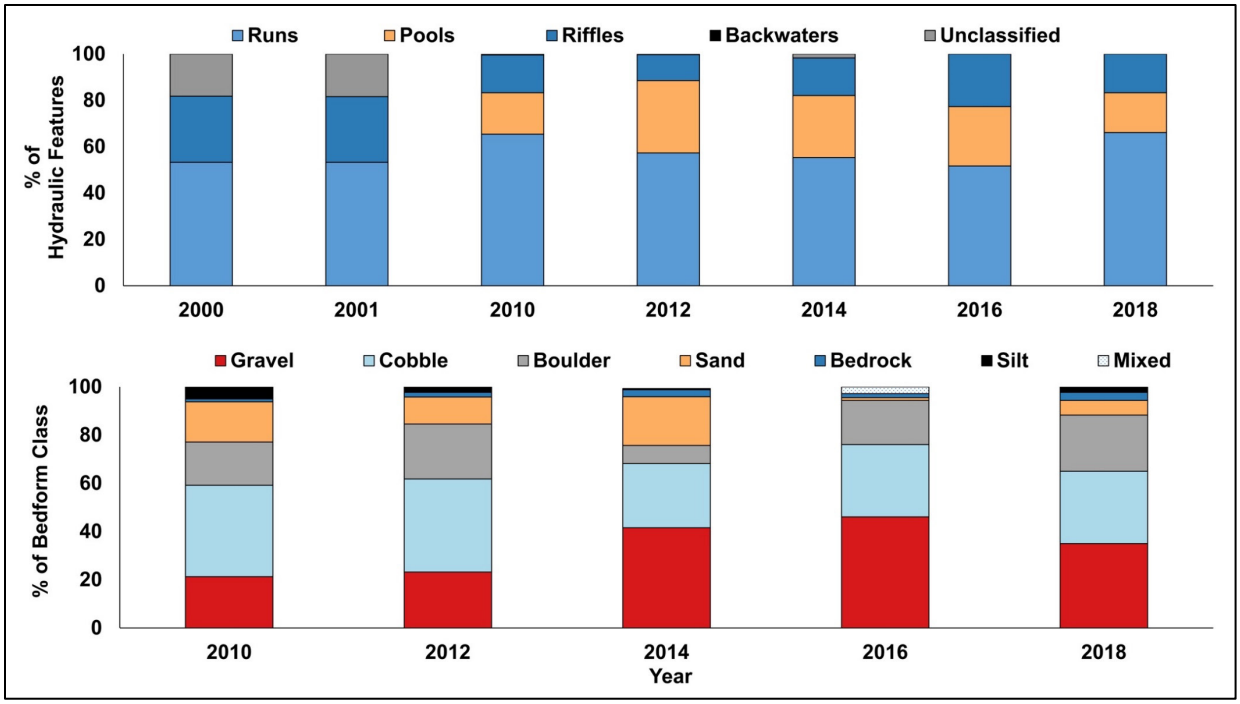


Figure 3.11.4-3. Percentage of hydraulic features (top) and bedform classes (bottom) along the Fremont River during 2000–2001 and biennially from 2010 to 2018.

The four most common native species in CARE require different amounts of pools, runs, riffles, and low velocity habitat, and a mix of various substrate features (Bower et al. 2008). Flannelmouth suckers are wide-ranging species that utilize a variety of habitats, including warm waters up to 27 °C (80.6 °F), while bluehead suckers prefer rocky substrates that tend to occur farther upstream than habitats typically occupied by flannelmouth suckers or roundtail chubs (Bezzerides and Bestgen 2002). Speckled dace are also found in a variety of habitats, though they're most common in "riffles and runs with moderate to rapid velocity water over gravel and cobble substrates" (Holden 1999). Mottled sculpins are benthic feeders that prefer gravel or rocky rubble substrates in fast-moving water near headwaters, creeks, and small rivers (Fuller and Neilson 2021). Roundtail chub prefer larger rivers with slow-moving, deep pools and riffles for cover and feeding, but they also reside in small tributary streams (Fuller and Neilson 2021).

The absence of roundtail chub is likely the result of many factors, including alteration of habitat, a waterfall barrier at the downstream end of the park, and competition with non-native species, but

they are extant in the Fremont River downstream (Bezzerides and Bestgen 2002). The three conservation species (roundtail chub, bluehead sucker, and flannelmouth sucker) are generally more abundant in river reaches where non-native species are absent or uncommon, regardless of habitat complexity (Walsworth et al. 2013). Notably, these three conservation species maintained growth rates and sizes in the presence of non-native species in the San Rafael River, a tributary of the Green River in Utah, even when their trophic niches overlapped completely (Walsworth et al. 2013).

Results for Pleasant Creek include four years of data on fish assemblages (Figure 3.11.4-4). As with the Fremont River, native fish represented most captures in each of the four years (73–100%). The native species captured were bluehead suckers, flannelmouth suckers, and speckled dace.

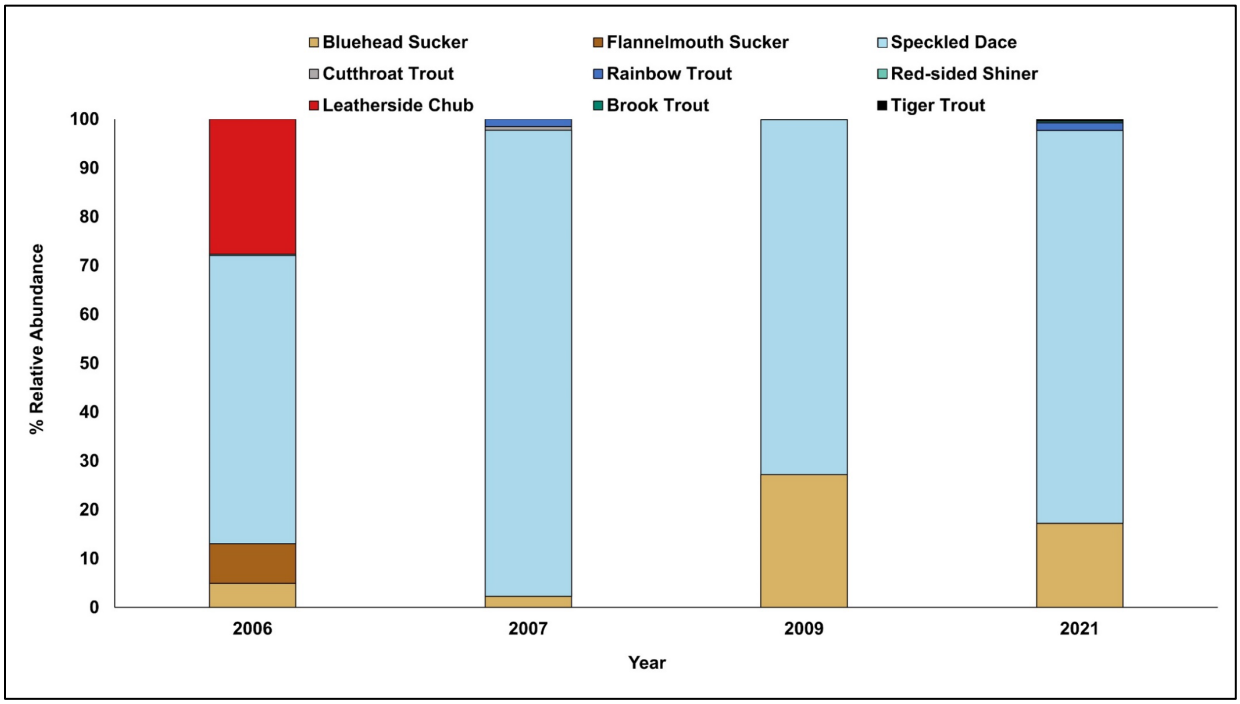


Figure 3.11.4-4. Percentage of fish by species captured in Pleasant Creek in 2006, 2007, 2009, and 2021.

In addition, a single cutthroat trout (*Oncorhynchus clarkii*) was reported by UDWR in 2007. Hepworth et al. (1993) stated that cutthroat trout historically occupied the Fremont River within the park but was extirpated; however, the authors did not note the year of extirpation.

Speckled dace represented 70% of all fish captured over the four years. Flannelmouth suckers represented ~4% of all captures and bluehead suckers represented 8.7% of all captures. Non-native fish included rainbow trout (2 in 2007 and 4 in 2021), redside shiner (1 in 2006), and leatherside chub (106 in 2006). Additionally, one brook trout (*Salvelinus fontinalis*) and one tiger trout, which is a hybrid between a brook trout and a brown trout, were captured. Leatherside chubs represented 13% of all captures, but all were captured in 2006. Again, no roundtail chubs were captured in Pleasant

Creek, nor were any mottled sculpin. Since there are only four years of data (and only one year in the last decade), we could not determine the current condition of the fish community in Pleasant Creek.

In 2006, Pleasant Creek's habitat was described as having a "fairly uniform gravel and bedrock channel with little complexity, composed of mostly shallow runs and low gradient riffles with small plunge pools" (Doyle et al. 2006b). Depth of water averaged 0.5 m (1.6 ft) and was about 2–3 m (6.6–9.8 ft) wide. In 2007, Golden and Black (2007) wrote that Pleasant Creek maintains important habitat for both flannelmouth and bluehead suckers. Based on this limited information, we could not evaluate the condition of habitat quality in Pleasant Creek.

There were few data for Sulphur Creek. In 1993, two leatherside chubs and eight speckled dace were captured (Borthwick 1993). In 2021, UDWR surveyed fish in Sulphur, Halls, and Oak creeks. In Sulphur Creek (five stations), observers counted 194 speckled dace (85%), seven bluehead suckers (3%), four flannelmouth suckers (1.7%), 23 leatherside chubs (10%), and one Utah sucker (<1%). In Halls Creek (four stations), observers counted 13 individuals, all of which were speckled dace. No fish were caught in Oak Creek (one station). There are no data for Polk Creek. Because of the limited amount or lack of data, the condition of the fish communities in these four creeks is unknown.

For the water quality indicator of condition, one of 26 water temperature measurements exceeded UDWQ standards in the Fremont River for samples collected during July 1975 to November 1992 (NPS 1994b). For Pleasant Creek, none of the three measurements exceeded UDWQ standards from July 1975 to May 1976, but one measurement came close at 19.5°C (67.1°F). Across all streams sampled from 2005 to 2018, an average of 15% of evaluations exceeded State of Utah water quality standards for temperature, and the proportion of evaluations exceeding temperature standards was greater during 2015–2018 (mean = 20%) than during 2009–2012 (mean = 11%) (only two sites were evaluated in 2005–2007 and neither exceeded temperature standards) (Figure 3.11.4-5).

The rise in the proportion of evaluations exceeding temperature standards was largely due to exceedances in Oak, Pleasant, and Sulphur creeks. Although both Halls Creek and the Fremont River site exhibited low to no exceedances during 2015–2018, UDWQ lists these streams (and their tributaries) as impaired for temperature. However, UDWQ (2020b) uses the cold water standard for the Fremont River, but the native species in CARE are warm water fishes (NPS, M. Trammell, fisheries biologist, comments to draft evaluation, 17 May 2021). Note also that UDWQ (2020b) uses the warm water standard for Halls Creek. Oak and Pleasant creeks and their associated tributaries were also listed as impaired for temperature using the cold water standard (UDWQ 2020b).

Four dissolved oxygen measurements were available for the Fremont River at the western boundary of CARE from June 1988 to November 1992 (NPS 1994b). None exceeded UDWQ standards. The only exceedances for dissolved oxygen occurred in 6% of samples collected in Halls Creek during 2005–2007 surveys. However, these exceedances occurred after a flood of "historic proportion in October 2006" (Thoma et al. 2008). A follow-up visit in November 2006 showed a return to normal conditions (Thoma et al. 2008). All other samples met reference criteria for dissolved oxygen in all years surveyed. Note that data for Oak, Pleasant, and Sulphur creeks were not collected during 2005–2007.

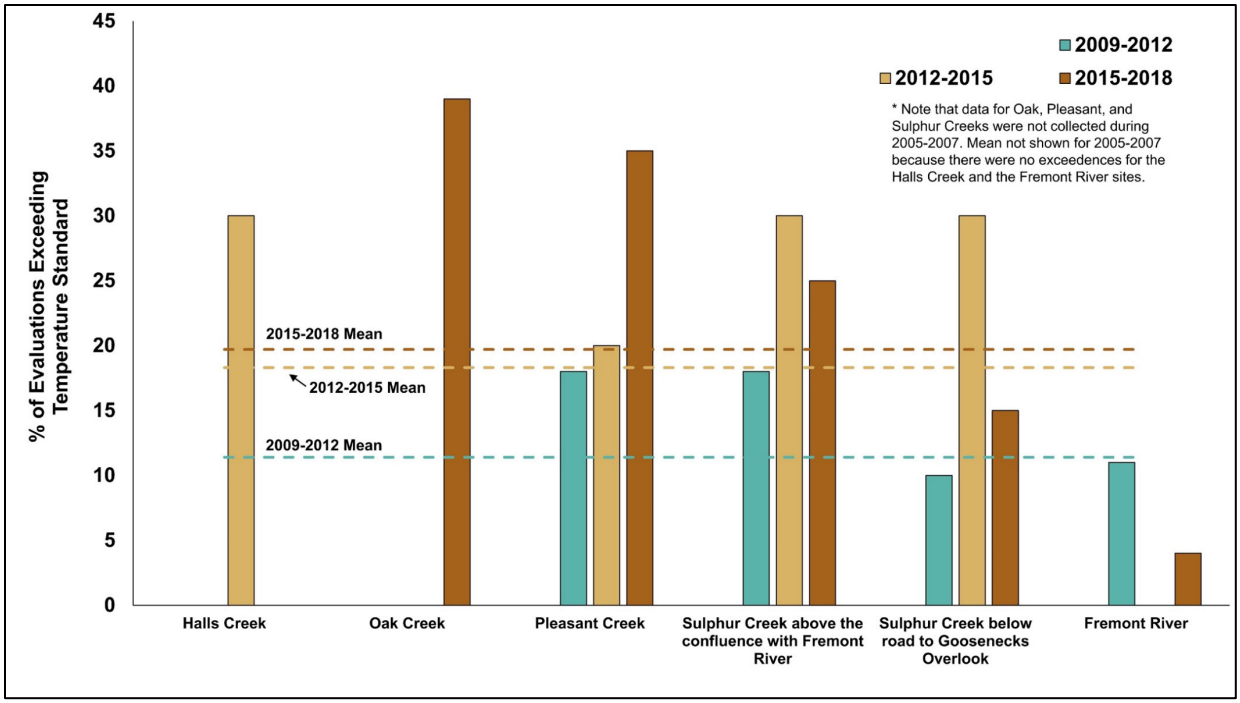


Figure 3.11.4-5. Percentage of evaluations exceeding State of Utah standards for temperature during three sampling periods at six locations in CARE. Means for each period are shown with dashed lines.

Most CECs in water samples collected at the Fremont River and Sulphur Creek sites were not detected; however, seven CECs were found in the Fremont River and three were found in Sulphur Creek (Table 3.11.4-1). These included four pesticides, one drug (caffeine), and four other wastewater indicators, including bisphenol A (commonly known as BPA), which is found in numerous items, including plastics. Two of the seven CECs detected were found in more than one year. Because these two CECs (2,4-D and Tris(1,3-dichloro-2-propyl)phosphate) occurred more than once, CECs did not meet reference criteria.

The 2015–2017 wet mercury deposition estimate was low for CARE, at 4.4 micrograms per square meter per year (µg/m^2/yr). However, these deposition estimates do not account for the dry deposition of mercury, which is a significant portion of the total deposition of mercury in arid regions (NPS, K. Taylor, data analyst, contribution to draft evaluation, 17 August 2021). The predicted methylmercury concentration in surface waters for CARE was estimated at 0.17 nanograms per liter (ng/L), which is very high (NPS, K. Taylor, data analyst, contribution to draft evaluation, 17 August 2021).

Of the 45 speckled dace captured in the Fremont River and tested for mercury in 2012, 49% had whole-body total mercury concentrations above the level which may affect fish health; 22% of the fish had whole-body total mercury concentrations above the level at which deleterious effects are likely to occur (Figure 3.11.4-6 top). Despite the intermediate position in the aquatic food web, speckled dace in CARE exhibited some of the highest mercury concentrations among fish species sampled in the 21 parks surveyed (Eagles-Smith et al. 2014). Because mercury accumulates up the food chain, the high amount of mercury in speckled dace suggests that lower-level invertebrates also

contain high mercury concentrations, and that other fish in the Fremont River are likely to have similar or higher concentrations than speckled dace. However, speckled dace have been found to have high amounts of mercury relative to other fish in the same system (Walters et al. 2015).

Table 3.11.4-1. Contaminants of Emerging Concern detected at the Fremont River and Sulphur Creek sampling sites. Note: "P" indicates Present; "ND" indicates Not Detected; "–" indicates CEC was not tested for that year.

Location	Contaminants of Emerging Concern	2012	2013	2014	2015
Fremont River	2,4-D [1]	P	P	ND	ND
	Caffeine [2]	ND	P	ND	ND
	Metalaxyl [1]	P	ND	ND	ND
	N,N-Diethyl-m-toluamide (DEET) [1]	P	ND	ND	ND
	p-Cresol [3]	–	P	ND	–
	Tris(1,3-dichloro-2-propyl)phosphate [3]	–	P	P	–
	Tris(2-butoxyethyl) phosphate [3]	–	P	ND	–
Sulphur Creek	4,4'-Isopropylidenediphenol (Bisphenol A or BPA) [3]	–	–	P	–
	Triclopyr [1]	–	–	ND	P
	Tris(1,3-dichloro-2-propyl)phosphate [3]	–	–	P	–

[1] = pesticides

[2] = drugs and pharmaceuticals

[3] = other wastewater indicator

Walters et al. (2015) found that 94% of speckled dace sampled in the Colorado River below the Glen Canyon Dam exceeded risk thresholds for fish health, 94% exceeded risk thresholds for human health, and 100% exceeded risk thresholds for piscivorous mammals. Fathead minnows (*Pimephales promelas*) exhibited similar risk threshold exceedances (Walters et al. 2015). In contrast, between 23% and 38% of bluehead suckers sampled exceeded risk thresholds for fish health, human health, and piscivorous mammal health. However, a proportion of all fish species sampled, including rainbow trout, common carp (*Cyprinus carpio*), and flannelmouth sucker, exceeded risk thresholds for fish, wildlife, and humans in the Colorado River (Walters et al. 2015).

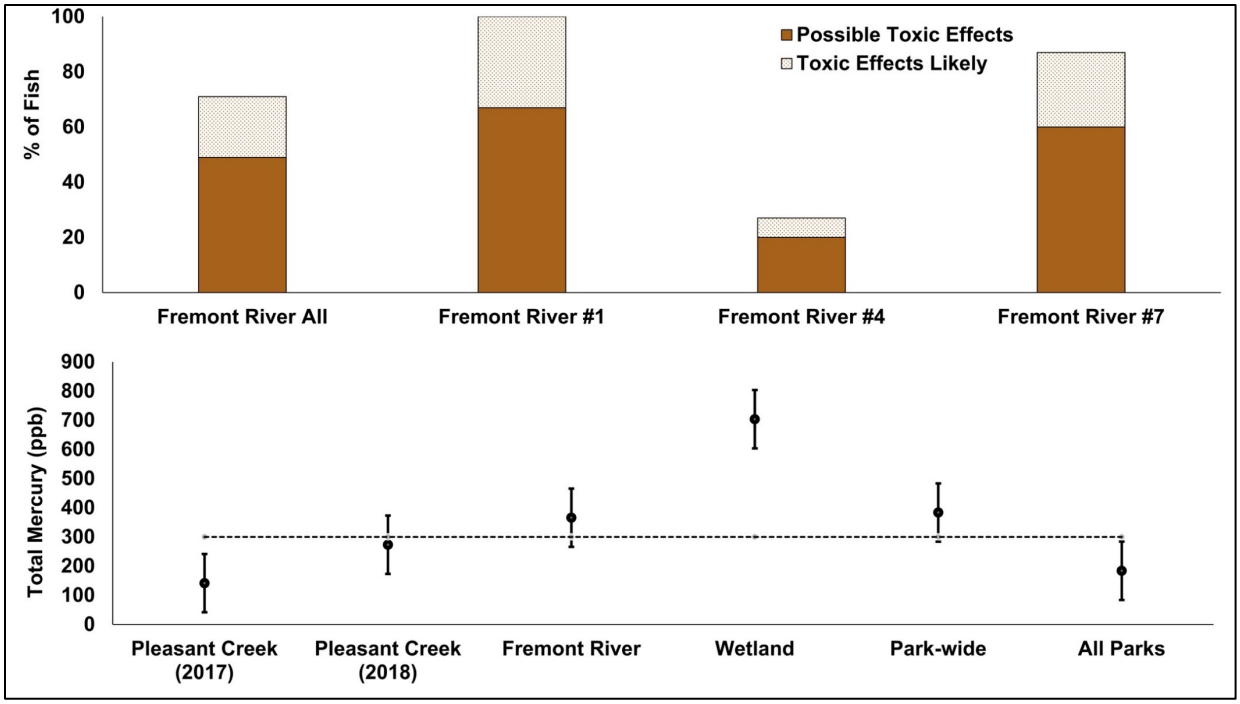


Figure 3.11.4-6. Percentage of speckled dace with mercury levels likely to cause harm to fish (top) and total mercury in dragonfly larvae from three sites in CARE compared to all 100 parks sampled (bottom). Dashed line indicates the level at which toxic effects in wildlife are likely to occur.

Differences in risk threshold exceedances are likely related to diet. For example, speckled dace consume Simuliids (blackflies) (NPS, M. Trammell, biologist, comments during manager-scientist meeting, 24 August 2021), 100% of which contained mercury concentrations that exceeded risk thresholds for fish (Walters et al. 2015). Walters et al. (2015) also found that 17% of suspended organic matter, and 57% *Gammarus* species (crustaceans) contained mercury thresholds that exceeded risk to fish health. None of the other sources of organic matter and primary producers (i.e., attached algae, benthic biofilm, diatoms attached to *Cladophora* sp., and fine benthic organic matter), Chironomids (non-biting midges), Lumbricids (earthworms), and New Zealand mud snails (*Potamopyrgus antipodarum*) exceeded risk thresholds for fish. Walters et al. (2015) write that damming rivers potentially increases mercury and selenium accumulation in food webs by linking lentic and lotic systems. Lentic (lake) systems often serve as sources of bioavailable forms of mercury and selenium.



Citizen scientists hiking to sampling location for the Dragonfly Mercury Project at CARE. Image Credit: NPS Air Resources Division, Dragonfly Mercury Project.

Although mercury levels in fish at other perennial streams in the park are unknown, Eagles-Smith et al. (2020) have shown that dragonfly larvae can serve as bioindicators of mercury in aquatic food webs. Dragonfly larvae sampling during 2017 and 2018 suggests that mercury is slightly below the threshold for adverse effects on wildlife in Pleasant Creek, indicating a moderate risk for impairment (though the standard error for 2018 exceeds the 300 parts per billion benchmark above which toxic effects are likely) (Figure 3.11.4-6 bottom). The means for the Fremont River and the wetland near Halls Creek exceeded this benchmark (high risk for impairment). Dragonfly larvae in CARE exceeded the average for all 100 parks and exhibited a total mercury concentration that was greater than 93% of parks sampled (USGS 2020b). Parks in the North American Deserts ecoregion, which includes CARE, exhibited the highest concentrations of mercury of the 13 ecoregions sampled in the U.S. (USGS 2020b).

The only other mercury data were for water samples tested from the mid-1970s to the early 1990s (NPS 1994b), and none exceeded USEPA standards for drinking water. The more recent data show that the reference criterion for mercury was not met. The risk to fish and wildlife from mercury at CARE is high (low confidence) based on elevated concentrations of mercury in both 1) dragonfly larvae, sampled at three CARE sites (Eagles-Smith et al. 2020), and 2) speckled dace, a small prey fish sampled at three sites from the Fremont River in CARE (Eagles-Smith et al. 2014).

The following information on sources of mercury (Hg) in CARE was provided by Colleen Flanagan Pritz, an ecologist with the NPS ARD in an email to J. Albright, NRCA program coordinator, on 1 September 2021. "The source of Hg in fish at the park is unknown but is presumed to be largely atmospheric deposition, and not from legacy gold mines or cinnabar ores—neither of which are prevalent in the immediate vicinity of CARE (Rytuba 2003; USGS 2003). Three Hg-emission sources in Utah fall in the top 100 of all Hg-emitting facilities in the U.S., according to the USEPA's national emissions inventory (NEI) (2020): hazardous waste incineration in Aragonite, UT; steel mill production in Plymouth, UT; and cement manufacturing in Morgan, UT. Per USEPA (2020) these source sectors accounted for a combined 21% of all Hg emissions in the U.S., while electric generating units (power plants) accounted for 55% of Hg emissions in the U.S. Petroleum refineries and compressor stations are also known sources of Hg emissions, though combined they contributed 2% of Hg emissions in the U.S. While local sources are important, Hg also arrives to CARE on regional and global transport pathways. Artisanal and small-scale gold mining operations are the largest contributor of global Hg emissions, and largely stem from regions in South America and Sub-Saharan Africa (UNEP 2019). Wildfires also re-emit previously deposited Hg."

"These emissions can travel long distances and deposit with rain, snow, or dust. Wright et al. (2013) suggested that dry Hg deposition is 3–4 times higher than wet Hg deposition at similar elevations to CARE across the West. Moreover, the desert landscape at CARE may especially facilitate the production of toxic methylmercury (MeHg). The rapid wetting and drying cycles and extreme hydrologic events create an environment where anaerobic bacteria thrive; these bacteria are necessary to convert inorganic Hg to MeHg. Further, the cryptobiotic crust on desert soils may provide a constant source of dissolved organic carbon (DOC) to the landscape, fueling methylation (C. Eagles-Smith, pers comm). Exposure to MeHg is generally more associated with conditions favoring MeHg production, such as moderately elevated levels of DOC and sulfate, than with loading or concentrations of inorganic Hg, but more intensive research will be necessary to tease out the sources and drivers of elevated Hg in biota at CARE and other desert parks like ZION, COLM [Colorado National Monument], and JOTR [Joshua Tree National Park]."

In summary, based on the data, the condition for the biological community in the Fremont River is fair (Table 3.11.4-2). While speckled dace, flannelmouth sucker, mottled sculpin, and bluehead sucker were consistently present, roundtail chub is extirpated. Although the proportion of native fish relative to non-native fish is high, there are eight confirmed non-native species in the Fremont River, and they were found at multiple sampling stations. There is also some evidence to suggest that non-native abundance has increased in recent years. Although the native species that are present are successfully reproducing and recruiting into multiple age classes, so are most of the non-native species. Confidence in the condition rating for the Fremont's biological fish community is high because systematic sampling has occurred since 2005 (with some earlier data) in the Fremont River. Trend is stable due to minor variability in richness and abundance. Sampling of biological communities in other streams in CARE has been less frequent and represents a data gap.

Table 3.11.4-2. Condition status of fish indicators.

Indicator	Condition Rating [1]	Trend	Condition Evaluation
Biological Community (Fremont River)	Fair	Stable	Selected biodiversity loss or change has caused measurable but not severe degradation in some attributes of ecological integrity. Confidence is high because of systematic sampling since 2005. The condition of biological communities for the other waterbodies assessed is unknown due to lack of data.
Habitat Quality (Fremont River)	Good/Fair	Stable	Habitat quality features are slightly altered or reduced but still considered suitable for native fish species. Confidence is medium because data were not reflective of each evaluated species' needs. The condition of habitat quality for the other waterbodies assessed is unknown due to lack of data.
Water Quality (Fremont River, Pleasant, Oak, Sulphur, & Halls creeks)	Good/Fair	Unknown	From 2005 to 2018, an average of 15% of evaluations exceeded Utah's water quality standards for temperature, and the proportion exceeding temperature standards was greater during 2015–2018 than during 2009–2012. All evaluations met standards for dissolved oxygen. The overall condition of water quality is good/fair, with medium confidence due to the UDWR's use of cold water standards for streams that support warm water fishes.
Contaminants (Fremont River, Pleasant & Sulphur creeks)	Fair/Poor	Unknown	There were seven CECs between the Fremont River and Pleasant Creek sites, two of which occurred recently. Mercury may be affecting fish health in Pleasant Creek and the Fremont River. Confidence in the condition of contaminants is medium because of the variability in data and unknown adverse effects from these contaminants.

[1] See Appendix B, Table B-6, for the 5-level condition rating statements for each indicator.

The available data for habitat quality in the Fremont River suggest the condition is good/fair, but confidence in the condition rating is medium because habitat data were general and not related to the specific needs of each species. Trend is stable because there has been little variability in the proportions of habitat characteristics over time. Habitat data for the remaining streams is a data gap.

Water quality data suggest good/fair conditions for the Fremont River, and Oak, Sulphur, Pleasant, and Halls creeks. While dissolved oxygen data met reference criteria, temperatures were often elevated in these streams, and the UDWQ considers them impaired as a result. "Despite the occasional exceedance of temperature criteria, Pleasant Creek and perhaps the other tributaries provide important habitat for warm water native fishes, so the temperature exceedances may not be of concern now but may become so if temperatures continue to warm in response to climate change" (NPS, M. Trammell, fisheries biologist, comments to draft evaluation, 17 May 2021). Confidence in the good/fair condition rating is medium because UDWR uses cold water standards for many of the streams in the park that support warm water fishes.

Although most CECs were not detected in either Sulphur Creek or the Fremont River, there were seven CECs between the two sampling sites, two of which occurred in at least two years. Lastly, mercury may be affecting fish health in Pleasant Creek and the Fremont River. Confidence in the fair/poor condition rating of contaminants is medium because of the variability in data (i.e., not all measures were collected for each stream surveyed).

Livestock trailing along Oak and Pleasant creeks could impact fish communities through erosion, siltation, increasing suspended sediments, and changes in overhanging vegetation that may influence stream temperature (NPS 2018b). Livestock trailing is permitted along Oak and Pleasant creeks, and trespass cattle in these areas outside of permitted trailing windows is not uncommon (NPS 2018b). A 2019 assessment of the riparian area of upper and lower Pleasant Creek found that the riparian area was in "proper functioning condition" along both reaches, but Oak Creek was rated as "nonfunctional" in 2019 and 2020, in part due to cattle trailing and grazing (Borthwick et al. 2019a; 2020). Furthermore, portions of Oak Creek have gone dry during the summer because of insufficient water levels in Bowns Reservoir to divert into the creek (Borthwick et al. 2020).

Low water flows contribute to elevated water temperatures. Hackbarth and Weissinger (2020) found that temperatures were most elevated during summer when stream flow is typically lower and air temperature is highest. Other stressors on the aquatic environment include visitor use, including swimming, hiking across streams, and illegal construction of rock dams to create swimming holes, which could inhibit fish movement and degrade habitat (NPS 2018a). Visitors may also contribute to stream pollution by applying insect repellent and sunscreen before wading or swimming.

Other threats and issues include invasive aquatic species, which were not assessed due to lack of data; hybridization; dewatering; dams; agricultural and industrial pollution; disease (e.g., whirling disease); and climate change (NPS 2018a). There is also the potential for flash floods to flush fish from stream reaches, which could result from natural disturbances made worse by climate change and various activities (e.g., fire management) (NPS 2018a).

Chapter 4. Management Considerations

Chapter 2 of the NRCA report considered the direct or indirect impacts that selected drivers and/or stressors may have (now or in the future) on focal resource conditions at CARE. Drivers and stressors often exert influences on resource conditions over a broader regional or landscape scale and may arise from inside or outside of CARE, which influences the feasibility of acting and affecting change in natural resource conditions.

Chapter 3 provided condition evaluations for each park-selected focal natural resource. The project team developed condition assessments for resources when adequate data were available or when expertise could be engaged to assess one or more indicators of condition. Resources lacking adequate data or expertise were evaluated at a lower level of evaluation (gap analysis) so that park managers could still receive useful condition-related information for future consideration.

This chapter suggests useful activities or responses based on a manager-scientist review of key findings and a discussion of next steps. Responses that include a more comprehensive, multi-resource/disciplinary and inter-divisional strategic approach when targeting follow-on activities or actions can benefit resource resiliency and achieving management goals in the near- or long-term planning horizon.

4.1. Manager-Scientist Review

To complete CARE's NRCA study, three manager-scientist meetings were held to review the findings of each evaluated resource. Another meeting outcome was to identify near-term and future responses/actions that may help managers further understand, maintain, and/or improve resource conditions. These responses considered the drivers and stressors occurring within and surrounding the park to differentiate between those that can be directly managed through specific actions (e.g., non-native invasive plant control), and those that are beyond a manager's ability to change (e.g., drought, climate change). Some require an inter-divisional focus and effort, while others benefit from external agency partnerships (e.g., watershed groups) due to the scale of the resource, drivers, or stressors.

To guide the manager actions discussion, seven general action categories (Table 4.1-1), which are based on the Conservation Measures Partnership (2016) *Classification of Conservation Actions and Threats* and the NPS Resource Stewardship Strategy activity categories (NPS n.d.), were used. Because subject matter experts attended each of CARE's manager-scientist meetings, the discussions primarily focused on actions related to research, monitoring, and inventory, rather than activities associated with the six remaining action categories. This does not reflect the need for additional types of actions to achieve the park's resource conservation goals.

Table 4.1-1. The action categories used to facilitate manager-scientist discussion of responses.

Action Categories [1]	Description [2]
Land, Water, or Species Field-based Management	These "on-the-ground" actions directly manage or restore sites, individual or groups of species, and/or ecosystems by targeting or mitigating a stress or threat(s).
Research, Monitoring, & Inventory	These actions collect data that can ultimately be applied to inform other conservation actions.
Education & Interpretation	These are actions directed at reducing threats by increasing positive behaviors. These include raising awareness of key issues at targeted audiences to affect behaviors.
Partnerships	These actions create and provide knowledge and data-sharing and capacity to address conservation goals on a larger scale.
Zoning & Planning	These types of actions create the conditions necessary for other conservation efforts to ultimately succeed.
Law Enforcement	These actions monitor and enforce compliance with existing laws, policies, and guidance to deter threats or promote positive actions.
Laws, Policies, & Guidelines	These actions develop and influence legislation, policies, and voluntary standards affecting conservation.

[1] Categories were adapted from the Conservation Measures Partnership (2016) actions classification levels v2.0 and common NPS Resource Stewardship Strategy activity categories v3.0 (NPS n.d.).

[2] Descriptions extracted and/or adapted from Conservation Measures Partnership (2016) actions classifications.

4.2. Review Outcomes Summary

The manager-scientist actions (i.e., responses) identified during CARE's meetings are summarized below by the resource groupings in which discussions occurred. Any manager question or need listed in Appendix A that remained unanswered in the NRCA is included in the summaries below to provide useful information for improving understanding, thus clarifying management action(s) in the future. *Suggestions regarding future studies or other actions to address the unanswered manager questions/needs are italicized.*

4.2.1. Night Sky and Air Quality Summary

CARE has an excellent opportunity to augment its night sky monitoring program by using donations to purchase more robust equipment. Training the park's interpreters on equipment use, including the use of the Bortle Dark-Sky Scale, and using IDA's more recent protocol on refining the number of sites (e.g., 5–6 locations) can guide CARE's program. Also, understanding the metrics and their suitability for a dark sky park like CARE is crucial. For example, the SQM is an inexpensive, coarse measuring device that works well in brighter sites, but it's variable for places like CARE because of its lack of sensitivity.

While an external threat to CARE's sky brightness may be light pollution from Torrey, UT, its largest, current night sky impact is lighting in the park. Taking images once a year toward Torrey, UT, using better equipment—NSNSD is developing a simplified all-sky monitoring device that takes a fisheye image of a calibrated sky once a year—and retrofitting lighting throughout the park, such as the amphitheater lamps, would improve the dark sky experience for visitors and wildlife. Also,

working with partners, such as Wayne County, on future development lighting (e.g., campground) will help maintain the very dark night sky in CARE and the surrounding region.

Related to clear skies is air quality, and while CARE has an on-site monitor that collects data to evaluate haze, an on-site ozone monitor would further improve the park's understanding of its air quality. The NPS ARD considers air quality concerns, regional representation, and data gaps when selecting ozone monitoring locations in national parks (NPS ARD 2021c) and has also reported that emissions from oil and gas development are not contributing to ozone formation (and nitrogen deposition) to a significant extent at the park. A data gap that remains, however, is knowing the amount of localized pollution from vehicle and OHV exhaust. This is especially important since OHVs are allowed a higher pollution level and emission standards are difficult to obtain.

A manager need identified during the NRCA study plan scoping process was an integrative landscape-scale monitoring framework for routinely assessing scenic view, night sky, and air quality resources. While scenic views were not evaluated in this report, working closely with the NPS ARD in the future will address that data need. Events that warrant re-evaluation of scenic views, night sky, and air quality include new oil and gas developments adjacent to the park, other developments surrounding the park, changes in lighting plans for nearby communities, and certain types of maintenance and/or developments within the park.

4.2.2. Soundscape Summary

In FY23, the park will repave the Scenic Drive and could consider quieter pavement options and treatments in its design. The costs for the quieter pavement are comparable to the traditional surface materials, and the quieter pavement is porous, trapping some noise in the material. Qualifying factors include having no areas that are >50 mph, and no areas with very slow speeds because the vehicle motor becomes more of the noise source than tires on pavement. Acoustic monitoring in the primitive and semi-primitive zones along the Scenic Drive would help inform future management actions for managing the increased visitor use.

Digital recorders have been deployed at CARE, and a year of continuous audio data and associated camera images are currently being analyzed. The analyses will provide baseline information about relative sound levels of OHV use adjacent to the park versus other vehicles and report the relative numbers of vehicles hourly. Pairing audio with camera images of vehicles may help identify adjacent OHV use more accurately.

A more focused, future monitoring effort is worth considering, possibly refining management questions, which will help identify the best monitoring tool(s) to use. Some factors managers considered include the direction of vehicle travel, which affects the amount of noise from engine load depending on whether a car is ascending or descending (e.g., in an area like Cathedral Valley) and ensuring timestamps are the same on the audio and camera equipment. Park managers could then compare the monitoring results to the NPS NSNSD geospatial sound level model to determine areas of higher-than-predicted impact, which will inform future management opportunities.

Similar to the night sky recommendations, understanding the sources of noise pollution in the park, and addressing them, is critical. Through these in-park efforts, managers could share activities that were successful at improving conditions in the park as other surrounding developments occur (e.g., planned campground along the Burr Trail). A framework for monitoring scenic views, sounds, and lights will help CARE managers focus on the most degraded areas of the park (e.g., Fruita District) and on impacts from external developments (e.g., oil and gas operations, campgrounds).

4.2.3. Springs, Seeps, & Tinajas, Riparian, & Fishes Summary

Three major action areas emerged from the water-based resources discussion. *The first was implementing a springs and groundwater study to understand surface-groundwater interactions and to inform where streams are gaining/losing groundwater across geologic formations.* The initial step would be to field inventory and verify spring and seep locations, sources, and types. The second step would be to define management priorities, then select a subset of representative or sentinel springs/seeps and develop a long-term protocol for monitoring discharge and basic water quality parameters; spring recharge areas could be determined via noble gas, stable isotope, and other environmental tracer analyses. The study would also inform how vulnerable streams are to climate change or groundwater pumping outside the park by pairing spring data (continuous or discrete) measurements to predict spring flow trends. A potential groundwater data source in Pleasant Creek is the Capitol Reef Field Station water treatment plant well, and possibly, some of the test wells drilled in the valley where water levels could be monitored.

The second major action identified was using the PFC approach to integrate resource monitoring (i.e., riparian and springs) by partnering with BLM and USFS to manage resources at the watershed level, especially along Oak and Pleasant creeks. The PFC rapid methodology is an efficient way to assess conditions across resources over time, to investigate surface water-groundwater interactions (i.e., discharge timing, magnitude, groundwater depth in creeks), and to determine the extent of riparian plant community change.

Preserving surface flows and protecting current conditions is CARE's primary objective, with the understanding that conditions likely won't get better due to climate change. Federal partners could identify exotic plant species that are high water users and collectively focus control efforts on the highest priority species. Also, identifying priority indicators/measures to define functionality in Oak Creek and the overall viability of habitat upstream of the dam may increase this area as a management priority because of other resources (i.e., owls and increased visitor use, such as canyoneering). Key questions include: What would be required to achieve stream function while sustaining livestock use? Are there opportunities to work with grazing permittees to adapt to yearly variability in conditions (e.g., trailer-haul instead of trailing)?

The third major action area discussed was to monitor the recruitment of fish populations in Pleasant, Sulphur, Halls, and Polk creeks using periodic repeat surveys, especially in Polk Creek where no data have been collected. Also, monitoring for streamflows, connectivity, and CECs, especially mercury, through repeat sampling (refer to mercury source discussion in the fishes condition assessment) is crucial for managing the park's native fishery.

An additional recommendation was to delineate tinajas quickly and accurately over large areas of the park using LiDAR.

4.2.4. Grasslands and Shrublands, Pinyon-Juniper Woodlands, and Rare Plants Summary

Regarding rare plants, CARE managers suggested identifying a statistically defensible study design that is viable over the long-term with limited personnel. Some study needs identified include a climate vulnerability assessment (as some plants are more drought tolerant), identifying plants of Tribal significance, surveying outside of previous allotments (so information is not just focused on grazing), and researching the importance of pollinators. *Coordinating data management and surveys with the USFS and BLM would benefit rare plant conservation in the region.* The data set is complicated and needs to be revamped for the park and other federal partners' use.

CARE managers are interested in the possibility of an onsite wet deposition monitoring station for nitrogen, depending on how nitrogen drives vegetation health in the park's dry desert environment. If nitrogen levels continue to increase, then an air quality station may inform data gaps, provide regional representation, and provide data to address air quality concerns (NPS ARD 2021c).

Currently, CARE is not a fire-prone ecosystem and is at a low fire/burn probability (NPS, Dave Firmage, fire ecologist, IFTDSS demonstration for CARE, manager-scientist meeting, 26 August 2021). However, if non-native invasive plants increase (e.g., brome) they would drive the potential for fire by changing the fuels profile. Contrasting the burn probability map with an overlay of CARE's critical resources (e.g., threatened and endangered species habitats) could be a next step via a risk/benefit analysis to help maintain the natural processes to the pinyon-juniper woodlands, using fire only if necessary. The Interagency Fuel Treatment Decision Support System (IFTDSS n.d.) may be a useful tool to analyze fire dynamics in the pinyon-juniper woodlands. Partnering with the USFS personnel to the west of CARE's boundary, where fire would likely originate, would benefit the resource at the landscape level.

To determine pivot points for grasslands/shrublands, gridded climate data (like PRISM and Daymet) are used for analyses. *Having weather stations co-located in allotments could help improve the accuracy of these pivot points.* Weather stations that are far away and gridded climate data sets can be biased if they are at an elevation different from an allotment, and they could miss convective storm events that supply a significant proportion of annual precipitation to an allotment (NPS, D. Thoma, landscape ecologist, comments to D. Witwicki, NPS NRCA Program manager, 2 November 2021). *It was also suggested that the Hartnet allotment receive more IIRH analysis to gain a post-grazing snapshot.*

4.2.5. Songbirds and Mexican Spotted Owl Summary

A focused songbird habitat or physiological needs-based (e.g., water and food availability) monitoring approach at the park may provide needed information to inform CARE's future management actions. Or, instead of adding more songbird monitoring sites at CARE, a subset of the NCPN parks monitored for songbirds (e.g., from CARE to the Colorado border) could be analyzed separately by group and provide results with higher confidence for specific habitat types. In addition, the Roberts et al. (2020) water balance study approach could focus on vulnerability by species of

management interest related to drought and other climate metrics. Also, focusing on areas where water is critical for songbirds, such as those along the Fremont River riparian zone, may help to focus management priorities. Visitor access to high priority habitat areas may need to be actively managed, especially given the campground's proximity to riparian habitat, which also presents an excellent interpretive opportunity. Partnering with the Utah Department of Transportation to manage the roadway along riparian habitat and with the USFS to manage adjacent pinyon-juniper habitat may assist managers with their conservation goals. Studying the effects of species, such as brown-headed cowbirds, and other disturbances like noise or vehicle exhaust on native songbird reproductive success is crucial for knowing which areas in the park serve as sources or sinks.

For the MSO, a multi-park occupancy study is needed to inform whether recovery efforts are meeting the regionwide USFWS delisting goal(s). GIS models could develop a sampling framework for areas in canyons. With the surge in park visitation at CARE, MSOs may not adapt quickly enough to the increased disturbances. Without this information, closing nesting/roosting sites is an effective management action.

As part of the occupancy study, less invasive survey methods to minimize disturbance include deploying sound devices and collecting feathers and pellets to differentiate individuals. The study would also inform whether MSOs use Oak Creek habitat in CARE or simply pass through to access the forested areas. The three MSO priorities identified are to:

- *Expand monitoring, with a shifting panel to monitor all sites every few years using calling visits and recorders.*
- *Inform connectivity and whether CARE is a source or a sink via feathers and pellets.*
- *Enlist the canyoneering community (e.g., collect feathers, watch protocol training video).*

Suggestions to improve the park's MSO Access database include the addition of a table that summarizes annual results for each site. Although there is a "site history" and a "monitoring data" table, these include entries for multiple within-year visits for a site and occasional annual site summary entries. In contrast, an annual site summary table would include: only one entry per site per year, summarizing the number of appropriately timed, within-season visits; the observer's judgement of occupancy (e.g., occupied, unoccupied, unknown); and whether a pair successfully fledged young (e.g., no nest attempt, failed nest attempt, successful nest attempt, and number of young, or unknown). This would make it easier to subset the data to include only those sites with enough within-season visits to derive annual occupancy and reproduction estimates. The "site history" and "monitoring data" tables also contain overlapping, duplicate entries, both across and within each table. Combining these two tables will facilitate data interpretation for determining occupancy.

4.2.6. Desert Bighorn Sheep Summary

There needs to be realistic and achievable reference criteria for CARE's bighorn sheep management goals and acceptance that pneumonia is and will continue to be present. Sheep develop resistance, and a more realistic management objective would be to identify ways to live with the disease, rather than exclude it through intensive management efforts (e.g., testing, culling). Also, the potential bighorn sheep population size modeled for CARE is high and shouldn't be used as an objective.

Understanding the core areas of habitat use throughout CARE, including lambing areas, will help managers enforce seasonal closures and limit interactions with visitors and other disturbances during lambing season. Understanding the subgroups of sheep through cost-effective, non-invasive approaches will inform connectivity and gene flow data gaps. Data from the Ceradini et al. (2020) camera-trap survey and fecal pellet sampling will help inform knowledge gaps and focus sampling efforts. The park's biologist suggested a focused meeting with state and other biologists post-NRCA to address park questions and needs and to develop active partnerships (NPS, M. Wehtje biologist, manager-scientist meeting planning email, 6 August 2021).

4.3. Conclusion

CARE managers need reliable information on current and trending conditions for the park's natural resources to make informed and timely decisions. This is not a straightforward task given the diversity of resources and breadth of drivers and stressors influencing conditions at the park and surrounding region. Rapidly increasing temperatures, more frequent droughts, non-native plants, and record-breaking numbers of park visitors are some of the driving forces and stressors affecting CARE's resources.

Often, management strategies will need to include multiple actions and/or address management needs for multiple, inter-related resources. By design, using the DPSSR framework, NRCA studies seek to deliver reliable resource condition information that CARE managers can apply to preserve, protect, and restore functional resource conditions in the park.

The collaborative and integrated actions identified in this report position the park to begin its Resource Stewardship Strategy and "to refocus its long-term management and funding needs", especially as CARE's Resource Management and Science Division transitions with new staff and develops a strategy to guide the increased park visitation to minimize resource impacts.

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Appendix A. CARE Manager Questions and Information Needs Summary

The questions and information needs listed in Table A-1 were posed by CARE managers during the NRCA study plan scoping process. When possible, information to address these questions and needs was presented in Chapters 2–4. If a question or need remained unaddressed in the NRCA, suggestions for informing the knowledge gap were presented in Chapter 4 resource summaries to inform future management activities.

Table A-1. CARE natural resource manager question or need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Question or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
An integrative landscape-scale monitoring framework for routinely assessing scenic view, night sky, and air quality resources.	We were unable to integrate scenic views into the night sky and air quality assessment; however, we provided an integrated approach to the two resource topics in the evaluation in this report.	• 2.5: Air Quality (Pollution) • 2.6: Resource Extraction • 3.1: Night Sky and Air Quality Condition Assessment
Which types of events should trigger immediate re-evaluation of the landscape-scale resources?	Events that may trigger a re-evaluation of these resources include oil and gas development adjacent to the park, other developments surrounding the park, changes in lighting plans for nearby communities, and certain types of maintenance and/or development within the park.	• 3.1: Night Sky and Air Quality Condition Assessment
What are some considerations for managing the soundscape in the front vs. backcountry areas of CARE?	Lowering speed limits, restricting the use of engine brakes, no idling rules, and repaving with quieter road surface materials could help reduce noise from the highway and Scenic Drive. Because general visitor use and backcountry use have increased, additional monitoring may be warranted. Recording devices may also be used to monitor the local soundscape around MSO territories. Clearly signing staying on trails and asking campers to camp in used areas will reduce the effects of disturbance on wildlife, including BHS.	• 3.2: Soundscape Gap Analysis • 3.9: Mexican Spotted Owl Gap Analysis • 4.2.2: Soundscape Summary • 4.2.5: Songbirds and Mexican Spotted Owl Summary

Table A-1 (continued). CARE natural resource manager question or need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Question or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
What are the sources of groundwater, as influenced by local geology, for springs?	Springs and seeps are poorly understood in CARE as little published information describes their source aquifers, contributing recharge areas, primary recharge mechanisms, and susceptibility to regional groundwater production. The Wingate, Navajo and Entrada sandstones, and Carmel Formation are likely the source aquifers for most CARE springs and seeps. In addition to the Carmel Formation, other minor aquifers including the Salt Wash Member of the Morrison Formation, Ferron and Emery Sandstone members of the Mancos Formation, Moenkopi Formation, and unconsolidated sediments (e.g., Quaternary alluvium) likely supply groundwater to most of the remaining CARE springs and seeps.	• 3.3: Springs, Seeps, & Tinajas Gap Analysis • 4.2.3: Water-based Resources Summary
Which springs are supplied by groundwater that originates within the park vs. outside the park?	Unconsolidated deposits have been targeted by many wells surrounding the park, especially to the west along the Fremont River Valley. The Moenkopi Formation can also be considered a locally important aquifer as it sources all of CARE's drinking water and supplies groundwater to a significant number of wells west of the park.	• 3.3: Springs, Seeps, & Tinajas Gap Analysis • 4.2.3: Water-based Resources Summary
What management actions can be taken to protect springs?	Actions may include fencing that excludes ungulates but allows access for smaller native mammals. Fencing would reduce erosion, spread of non-native species, and trampling of vegetation. Other actions include controlling non-native aquatic invertebrates and rehabilitating spring orifices to improve flow. To mitigate declines in discharge, perhaps installing mechanisms that pool and direct water may maintain spring ecosystems. Removal of non-native invasive plants with high water demand (e.g., tamarisk) may also help protect and restore springs.	• 3.3: Springs, Seeps, & Tinajas Gap Analysis
What is the amount/timing of precipitation needed to retain water year-round in tinajas, and how does that vary with size?	Precipitation, pool volume and dimensions, temperature and other factors governing evaporation (e.g., the degree of shading), wildlife demands (e.g., transpiration), and the permeability of host geologic materials influence how long water is retained in tinajas. Tinaja pools with volumes greater than 90 m^3 (3,178 ft^3) are usually perennial unless they are shallow (0.4 m [1.3 ft]) or there is a prolonged drought. A study of 463 pools at CARE found that pool water volume ranged from 0 m^3 to 1,532 m^3 (54,102 ft^3), with a mean volume of 21 m^3 (742 ft^3), but most pools were ≤15 m^3 (530 ft^3). This suggests that most pools in CARE are ephemeral. As the climate warms and becomes drier, perennial tinajas may become ephemeral.	• 3.3: Springs, Seeps, & Tinajas Gap Analysis

Table A-1 (continued). CARE natural resource manager question or need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Question or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
Are there cultural features associated with springs that may have augmented groundwater recharge in the past as found in some other parks (e.g., pre-European reservoirs and check dams)?	There are no known cultural features that may have augmented groundwater recharge at springs in CARE. Although the ethnographic overview mentions the importance of springs to previous inhabitants of the region, the report does not mention check dams or pre-European reservoirs.	• N/A
How do the bank treatments along the Fremont River [established] to protect State Route 24 affect the geomorphology and impact the associated riparian system?	In 2019, the NPS Water Resources Division found no areas of extensive erosion to either the streambank or channel that could be directly attributed to the bank stabilization structures. The larger issue is the 1962 re-route of the stream channel (from an oxbow to a bedrock channel that cut off the oxbow) as part of Highway 24 construction, which has resulted in bedrock incision and potential threats to the stability of existing infrastructure and riparian resources throughout the corridor (Martin 2021).	• 3.4: Riparian Gap Analysis
What are the impacts from trailing on Oak and Pleasant creeks and grazing on perennial streams?	In riparian areas, cattle grazing and trailing is more concentrated and damaging to plants than in other areas because grazers are more concentrated in the narrow zone of a riparian corridor. Consequences of grazing and trailing observed in CARE include compaction of soils, reduced water infiltration, bank destabilization, trampling of native plants, and the introduction of non-native and invasive species. While these impacts have been observed at both Oak and Pleasant creeks, Pleasant Creek has maintained good condition while Oak Creek is non-functional.	• 3.4: Riparian Gap Analysis • 4.2.4: Grasslands and Shrublands, Pinyon-Juniper Woodlands, and Rare Plants Summary
Are pinyon-juniper woodlands in the park “overstocked” (i.e., advanced past a density threshold that poses an enhanced risk of wildfire and/or understory loss)?	No. While pinyon-juniper woodlands make up a majority of the park’s vegetation, nearly 90% of those woodlands are in a low-density, early development phase. An estimated 4%–6% of CARE woodlands have reached a stage that is considered “fully occupied,” yet even here, canopy cover does not reach 50%.	• 3.5: Pinyon-Juniper Woodlands Condition Assessment
Is there a threshold of soil moisture that would affect pinyon-juniper woodlands?	Such a threshold exists, but an exact lower limit of necessary soil moisture has not been identified and would be difficult to monitor. Two-needle pinyon pine requires more moisture in summer than Utah juniper, which has been observed to lose as little as 0.2 mm of water per day through evapotranspiration. Evidence of dieback from recent droughts suggest that some pinyon-juniper woodlands in the region have approached the threshold.	• 3.5: Pinyon-Juniper Woodlands Condition Assessment

Table A-1 (continued). CARE natural resource manager question or need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Question or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
How are grasslands/shrublands recovering from grazing? What is the impact of current grazing and trailing on grasslands/shrublands, and are management actions resulting in improvements to rangeland condition?	Rock Springs and Cathedral were in good condition, while the Sandy 3 and Hartnet allotments departed substantially from reference criteria. The Hartnet allotment was retired in 2018. In contrast, both the Cathedral and Rock Springs allotments have been retired for several decades, allowing time for recovery. The impacts of grazing on grasslands/shrublands include impaired hydrologic function, soil and site stability, and biotic integrity in allotments recently retired or that continue to be grazed. The good conditions for the Cathedral and Rock Springs allotments several decades post-grazing suggest that the Hartnet allotment may recover from the effects of grazing.	• 3.6: Grasslands and Shrublands Condition Assessment • 4.2.4: Grasslands and Shrublands, Pinyon-Juniper Woodlands, and Rare Plants Summary
How important is CARE's rare plant population(s) with respect to entire population(s)?	More than half (57%) of the 426 rare plant sites mapped across the 25 target species reported in the gap analysis were mapped in CARE, and many of these sites represent at least 25% of all known sites according to NatureServe.	• 3.7: Rare Plants Gap Analysis
How do rare plants in CARE compare to populations outside the park?	Most (~80%) of the 184 sites evaluated in the park were rated as excellent or good for quality (population size, vitality, and vigor), viability (long-term prospects of maintaining the quality rating), habitat condition, and defensibility (possibility of protecting the site from extrinsic human factors). Outside CARE, only 60% of the 156 sites were rated as excellent or good across the four measures. While the status of knowledge in CARE is excellent, there has been less effort to monitor plant populations outside the park and the status of knowledge there is considered poor (Manzanita Botanical Consulting, J. H. Hornbeck, botanist, comments to draft assessment, 1 July 2021). Although we consider CARE to be extremely important to the overall conservation of rare plants, owing to its protected status, this question can't be answered fully due to the lack of regular monitoring outside the park.	• 3.7: Rare Plants Gap Analysis • 4.2.4: Grasslands and Shrublands, Pinyon-Juniper Woodlands, and Rare Plants Summary
What should be the rotation for future rare plants monitoring?	Six main monitoring strategies were suggested: annual (2.6%), biennial (<1%), every 3–5 years (<1%), periodic (56%), regular (16%), and event-specific monitoring (2.3%). Managers also identified the need to clarify their questions and to develop a statistically defensible study design that is viable over the long term with limited personnel.	• 3.7: Rare Plants Gap Analysis • 4.2.4: Grasslands and Shrublands, Pinyon-Juniper Woodlands, and Rare Plants Summary

Table A-1 (continued). CARE natural resource manager question or need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Question or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
Given the widespread loss of birds nationwide, how are CARE's songbird populations faring?	We rated the condition of songbird community composition as good/fair because some species of concern and/or obligate and dependent species in each of the three habitat types (riparian, pinyon-juniper, grasslands-shrublands) have exhibited declines at larger spatial scales (i.e., state and NCPN). There are also indications of declines for some species at the park level, including western meadowlark and lark sparrow. However, trends in abundance or density could be the result of factors other than conditions inside the park, especially for neotropical migrants, which cover broad geographic areas throughout their life cycle. Confidence in the condition rating was low because there are songbird data for limited areas of three habitats in the park, and none of the studies were designed for inference at the park level. While these data show that the suite of obligate and dependent species within each of the three habitat types are present, there are data gaps concerning population size and nesting success. Due to the small sample sizes, we could not extrapolate the data to respective habitats park wide.	• 3.8: Songbirds Condition Assessment • 4.2.5: Songbirds and Mexican Spotted Owl Summary
How has Mexican spotted owl (MSO) occupancy changed in the park?	We could not determine occupancy because traditional approaches to obtaining occupancy were not implemented at CARE, owing to the remote and rugged nature of MSO habitat. One of the primary objectives of earlier surveys was to document distribution of owls in the park and identify PAC sites. Site or territory occupancy relies on multiple, appropriately timed visits to determine if a site was occupied by a breeding pair, a single individual, a non-breeding pair, or no owls. See recommendation below to address this question.	• 3.9: Mexican Spotted Owl Gap Analysis • 4.2.5: Songbirds and Mexican Spotted Owl Summary
How are MSO faring in the greater region given that CARE is a small, narrow park?	We were unable to answer this question given the available data. During the 14 September 2021 manager-scientist meeting, David Willey, MSO biologist at Montana State University, recommended implementing a landscape-scale approach to monitoring MSO that would answer this question. The survey area would include CARE, GLCA, ZION, CANY, and GSENM. Increased collaboration between these units would augment existing surveys and improve managers' understanding of MSO population dynamics (e.g., source-sinks) at the scale at which MSO use the landscape (e.g., dispersal).	• 4.2.5: Songbirds and Mexican Spotted Owl Summary

Table A-1 (continued). CARE natural resource manager question or need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Question or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
A management decision framework for evaluating the removal of diseased bighorn sheep (BHS) would be helpful	The NPS Biological Resources Division's (2019) Best Management Practices brief was provided but working with UDWR to identify realistic goals related to diseased individuals would also be beneficial.	• NPS BRD Brief • 3.10: Desert Bighorn Sheep Gap Analysis • 4.2.6: Desert Bighorn Sheep Summary
Park has difficulty obtaining data about park's BHS herds, including abundance estimates and disease surveys.	This remains unaddressed, but Morgan Wehtje., CARE biologist, suggested a post-NRCA manager-scientist discussion with the state and other BHS managers to define CARE's management goals for BHS.	• 4.2.6: Desert Bighorn Sheep Summary
What is the abundance, distribution, and health of the native fish community?	Fish were surveyed in the Fremont River (1992, 1993, biennially from 2005 to 2018), Pleasant Creek (2006, 2007, 2009, 2021), Sulphur Creek (1993, 2021), and Halls Creek (2021). Five native species were encountered. Of these, the most common species were speckled dace, flannelmouth sucker, and bluehead sucker. The two other native species included a single cutthroat trout captured Pleasant Creek in 2007 and mottled sculpin captured in the Fremont River, which was also rare. There were too few data to summarize the fish community in Sulphur and Halls creeks. No fish were captured in Oak Creek during 2021. Mercury levels in speckled dace and dragonfly larvae sampled in CARE are some of the highest in the national park system. Most contaminants of emerging concern (CEC) in water samples collected at the Fremont River and Sulphur Creek sites were not detected; however, seven CECs were found in the Fremont River and three were found in Sulphur Creek. These included pesticides, caffeine, and bisphenol A.	• 3.11: Fishes Condition Assessment • 4.2.3: Water-based Resources Summary

Appendix B. Condition Rating Statements

The five-level condition rating statements for the night sky (Table B-1) and air quality (Table B-2), pinyon-juniper woodlands (Table B-3), grasslands and shrublands (Table B-4), songbirds (Table B-5), and fishes (Table B-6) condition assessments are presented below.

Table B-1. Condition rating statements for the status of night sky indicators.

Condition Rating [1]	Illuminance	Luminance | (SOM values)	Anthropogenic Light Pollution (ALR values)	Sky Quality
Good	The natural reference for moonless nights is 0.8 mlux for horizontal illuminance and 0.4 mlux for vertical illuminance.	≥21.60.	<2.00.	Bortle class is 1–3. A limiting magnitude value of 7.4 is excellent.
Good/Fair	–	–	–	–
Fair	Departures from the natural references will be discussed in the assessment because reference criteria are not established.	21.20–21.59.	2.00–18.00.	Bortle class is 4. Limiting magnitude ranges between >6.3 to <7.4.
Fair/Poor	–	–	–	–
Poor	–	<21.20.	<18.00.	Bortle class is 5–9. A limiting magnitude value of <6.3 is significantly degraded.

[1] Values are based on the NPS Natural Sounds and Night Skies Division benchmarks (Moore et al. 2013; Hung et al. 2019.

Table B-2. Condition rating statements for the status of air quality indicators.

Condition Rating [1]	Visibility	Ozone
Good	<2.0 dv	≤ 54.9 ppb
Good/Fair	–	–
Fair	2.0–8.0 dv	55.0–70.9
Fair/Poor	–	–
Poor	>8.0 dv	≥ 71.0

[1] Values are based on the NPS Air Resources Division benchmarks (NPS ARD 2021a).

Table B-3. Condition rating statements for the status of pinyon-juniper woodlands indicators.

Condition Rating	Tree Density	Crown Cover Increase	Obligate Songbirds	Age Class Distribution
Good	Stand density and crown cover remain in the early-development stage. Fewer than 10% of plots exceed stand density and crown canopy thresholds.	Change in crown cover is less than 2% per decade, with little evidence of pinyon and juniper infill or expansion.	Abundance of woodland-dependent songbirds reflects near-pristine conditions with stable or increasing populations of both species.	At least 60% of woodlands are in the early-development stage, and no more than 10% is nearing a closed-canopy condition.
Good/Fair	Stand density and crown cover are mostly in the early-development stage.	Change in crown cover is less than 2% per decade for most plots. Woodland expansion may be occurring, but the process is slow.	Abundance for one species has decreased but not significantly; the other species is stable or increasing.	At least 50% of woodlands are in the early-development stage, and no more than 20% is nearing a closed-canopy condition.
Fair	Stand density and crown cover have reached a closed-canopy stage (>35%) in many stands, and an equal number of stands are in a mid-development stage.	Crown cover is increasing, both within existing stands and newly established ones.	Songbird abundance is decreasing, but by <10%. Focal species are present, and breeding is observed every year.	Woodland age classes are evenly distributed across the landscape, with less than 1/3 in a closed-canopy condition.
Fair/Poor	Stand density and crown cover have reached a closed-canopy stage in as much as half of the park, but a significant portion of the park remains in an early or mid-development stage.	Crown cover is increasing via both infill and expansion, and the rate of expansion appears to be accelerating into grass and shrub communities.	Songbird abundance is decreasing for focal species, but they are present and believed to be breeding annually.	Woodland age classes are relatively evenly distributed but closed-canopy condition is the most common state.
Poor	Stand density and crown cover is above the 35% threshold over more than half of the park.	Crown cover is increasing in existing stands but at a declining rate, because >50% of the park's woodlands have reached a stage where infill no longer occurs. Expansion into grass and shrub continues at a steady or increasing rate.	One or all focal species is declining, and individuals are not detected every year.	Woodland age classes are skewed toward a closed-canopy condition. Some stands no longer support understory vegetation.

Table B-4. Condition rating statements for the status of grasslands and shrublands indicators.

Condition Rating	Biotic Integrity	Soil Stability	Hydrologic Function	Nitrogen
Good	Rangelands in the park are diverse and ecologically complex, dominated by native grass, grass-like plants, forbs, and shrub communities.	Rangelands in the park have stable, non-degraded soils, and properly functioning hydrologic and biotic processes that are vital to the persistence and resilience of the range.	Rangelands in the park capture, store, and safely release water from rainfall, runoff, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.	Nitrogen deposition is ≤1 kg/ha/yr.
Good/Fair	There is a slight to moderate departure from good condition.	There is a slight to moderate departure from good condition.	There is a slight to moderate departure from good condition.	–
Fair	There is a moderate departure from good condition.	There is a moderate departure from good condition.	There is a moderate departure from good condition.	Nitrogen deposition is 1–3 kg/ha/yr.
Fair/Poor	There is a moderate to extreme departure from good condition.	There is a moderate to extreme departure from good condition.	There is a moderate to extreme departure from good condition.	–
Poor	There is an extreme to total departure from good condition.	There is an extreme to total departure from good condition.	There is an extreme to total departure from good condition.	Nitrogen deposition is >3 kg/ha/yr.

Table B-5. Condition rating statements for the status of songbirds indicator.

Condition Rating	Community Composition
Good	Songbird community composition reflects near pristine conditions with no indication of compromises to ecological integrity. For example, all or nearly all potential species are present; trends in species of concern are stable or even increasing; and key indicator species are present.
Good/Fair	Some changes in songbird community composition may have occurred, but degradation is not yet measurable. For example, nearly all potential species are present (including key indicators species), but trends in some species of concern indicate possible declines. However, declines are not statistically significant.

Table B-5 (continued). Condition rating statements for the status of songbirds indicator.

Condition Rating	Community Composition
Fair	Songbird community composition indicates loss or change in ecological integrity, but changes are not severe. For example, most potential species are present, but some key species are absent; and/or trends in species of concern suggest possible declines, but declines are either not significant or the species in decline are still considered relatively abundant.
Fair/Poor	Songbird community composition indicates loss or change in ecological integrity. Changes may be severe but are not necessarily widespread across all attributes of community composition. For example, richness is high, but species of concern are in decline.
Poor	Songbird community composition suggests severe degradation in ecological integrity. For example, key indicator species are absent; abundance has declined for species of concern, or some species of concern are absent altogether; and/or species richness is substantially lower than expected.

Table B-6. Condition rating statements for the status of fishes indicators.

Condition Rating	Biological Community	Habitat Quality	Water Quality	Contaminants and Pollution
Good	Biodiversity reflects pristine or near-pristine conditions with full suite of native species and no non-native species present, or if present, non-native species do not have measurable impacts on the native fish community.	Habitats along most stream reaches are in pristine or near-pristine conditions with suitable benthic and hydraulic diversity to support the needs of native fish species.	All water quality measures meet aquatic life requirements.	Contaminants have not been documented or do not appear to have the potential to negatively affect fish.
Good/Fair	Selected biodiversity loss or change has occurred and/or non-native species are present, which may preclude full community development and function, but has not yet caused measurable degradation.	Habitat quality features are slightly altered or reduced but still considered suitable for native fish species.	One or more water quality measures suggest the potential for impacts to fishes, but impacts have not been reported.	Selected contaminants are suspected and may degrade some attributes of ecological integrity but have not yet been known to cause measurable degradation.

Table B-6 (continued). Condition rating statements for the status of fishes indicators.

Condition Rating	Biological Community	Habitat Quality	Water Quality	Contaminants and Pollution
Fair	Selected biodiversity loss or change has caused measurable but not severe degradation in some attributes of ecological integrity.	There is measurable but not severe degradation in benthic substrate composition and/or hydraulic features. Most required features are present, especially those required for reproduction.	While basic water quality measures support aquatic life, water quality problems have likely caused measurable impacts. However, effects are localized and not widespread or persistent.	Selected contaminants have been documented and may degrade some attributes of ecological integrity but have not yet been known to cause measurable degradation.
Fair/Poor	Selected biodiversity loss or change has caused severe degradation in some but not all attributes of ecological integrity.	Selected habitat loss or alteration has caused severe degradation in some, but not all aspects of benthic substrate diversity and hydraulic features.	Water quality problems have almost certainly caused severe impacts that are either widespread and/or persistent.	Selected contaminants are present and at levels that may degrade some attributes of ecological integrity.
Poor	Selected biodiversity loss or change has caused severe degradation in most if not all attributes of ecological integrity.	Habitats along most stream reaches are severely degraded with unsuitable benthic and hydraulic diversity that does not support the needs of native fish species.	Measures of water quality are not consistent with supporting aquatic life. Impacts are severe, persistent, and widespread.	Selected contaminants are present and have caused measurable degradation in ecological integrity.

Appendix C. Dominant and Non-dominant Plants at Springs

For lists of the dominant and non-dominant plant species by life form, name, nativity, wetland status, and endemism observed at the 27 springs monitored by CARE staff, refer to Tables C-1 and C-2.

Table C-1. Dominant plant species by life form, nativity, wetland status, and endemism observed at 27 springs and seeps (SSI 2021).

Life Form	Scientific Name	Common Name	Nativity	Wetland Status [1]	Endemic
Trees	*Abies balsamea* var. *phanerolepis*	Balsam fir	Native	UPL	No
	Populus angustifolia	Narrowleaf cottonwood	Native	FACW	No
	Populus fremontii	Fremont cottonwood	Native	FACW	No
	Shepherdia argentea	Silver buffaloberry	Native	UPL	No
Shrubs	*Amelanchier* sp.	Serviceberry	Native	FACU	No
	Chrysothamnus sp.	Rabbitbrush	Native	FAC	No
	Ericameria nauseosa	Rubber rabbitbrush	Native	UPL	No
	Rhus trilobata	Skunkbush sumac	Native	UPL	No
	Salix exigua	Narrowleaf willow	Native	FACW	No
	Sarcobatus sp.	Greasewood	Native	FACU	No
	Shepherdia rotundifolia	Roundleaf buffaloberry	Native	UPL	No
	Tamarix spp.	Tamarisk	Non-native	FAC	No
Graminoids	*Bromus tectorum*	Cheatgrass	Non-native	UPL	No
	Distichlis spicata	Saltgrass	Native	FAC	No
	Equisetum laevigatum	Smooth horsetail	Native	FACW	No
	Juncus sp.	Rush	Native	Unknown	No
	Juncus arcticus	Arctic rush	Native	FACW	No

[1] OBL (obligate wetland) = almost always occurs in wetlands; FACW (facultative wetland) = usually occurs in wetlands but occasionally found in uplands; FAC (facultative) = occurs in either wetlands or uplands: FACU (facultative upland) = sometimes occurs in wetlands but usually occurs in uplands; UPL (upland) = almost always occurs in uplands.

Table C-1 (continued). Dominant plant species by life form, nativity, wetland status, and endemism observed at 27 springs and seeps (SSI 2021).

Life Form	Scientific Name	Common Name	Nativity	Wetland Status [1]	Endemic
Gamanoids (continued)	*Phragmites* sp.	Reed	Unknown	Unknown	No
	Phragmites australis	Common reed	Non-native	FACW	No
	Schoenoplectus pungens	Common threesquare	Native	OBL	No
	Scirpus sp.	Bulrush	Unknown	Unknown	No
	Sporobolus sp.	Dropseed	Unknown	Unknown	No
	Sporobolus heterolepis	Prairie dropseed	Native	UPL	No
Forbs/Herbs	*Asclepias* sp.	Milkweed	Unknown	Unknown	No
	Aster sp.	Aster	Unknown	Unknown	No
	Castilleja linariifolia	Wyoming Indian paintbrush	Native	UPL	No
	Equisetum sp.	Horsetail	Unknown	Unknown	No
	Symphyotrichum chilense	Pacific aster	Native	FAC	No
	Xanthium strumarium	Rough cocklebur	Native	FAC	No

[1] OBL (obligate wetland) = almost always occurs in wetlands; FACW (facultative wetland) = usually occurs in wetlands but occasionally found in uplands; FAC (facultative) = occurs in either wetlands or uplands: FACU (facultative upland) = sometimes occurs in wetlands but usually occurs in uplands; UPL (upland) = almost always occurs in uplands.

Table C-2. Non-dominant plant species by life form, nativity, wetland status, and endemism observed at 27 springs and seeps (SSI 2021).

Life Form	Scientific Name	Common Name	Nativity	Wetland Status [1]	Endemic
Trees	*Abies concolor*	White fir	Native	UPL	No
	Clematis ligusticifolia	Western white clematis	Native	FAC	No
	Juniperus osteosperma	Utah juniper	Native	UPL	No
	Pinus edulis	Twoneedle pine	Native	UPL	No
	Quercus gambelii	Gambel oak	Native	UPL	No
Shrubs	*Artemisia dracunculus*	Tarragon	Native	UPL	No
	Berberis sp.	Barberry	Native	Unknown	No
	Chrysothamnus viscidiflorus	Spearleaf rabbitbrush	Native	FAC	No
	Eastwoodia elegans	Yellow mock aster	Native	UPL	No
	Elaeagnus angustifolia	Russian olive	Non-native	FAC	No
	Ephedra viridis	Mormon tea	Native	UPL	No
	Sarcobatus vermiculatus	Greasewood	Native	FACU	No
Graminoids	*Achnatherum hymenoides*	Indian ricegrass	Native	UPL	No
	Agropyron cristatum	Crested wheatgrass	Non-native	UPL	No
	Agrostis gigantea	Redtop	Non-native	FACW	No
	Agrostis stolonifera	Creeping bentgrass	Non-native	FACW	No
	Elymus elymoides	Squirreltail	Native	FACU	No
	Hesperostipa comata	Needle and thread	Native	UPL	No
	Muhlenbergia asperifolia	Scratchgrass	Native	FACW	No
	Phalaris arundinacea	Reed canarygrass	Native	FACW	No
	Scirpus americanus	Chairmaker's bullrush	Native	OBL	No
	Sporobolus airoides	Alkali sacaton	Native	FAC	No

[1] OBL (obligate wetland) = almost always occurs in wetlands; FACW (facultative wetland) = usually occurs in wetlands but occasionally found in uplands; FAC (facultative) = occurs in either wetlands or uplands: FACU (facultative upland) = sometimes occurs in wetlands but usually occurs in uplands; UPL (upland) = almost always occurs in uplands

Table C-2 (continued). Non-dominant plant species by life form, nativity, wetland status, and endemism observed at 27 springs and seeps (SSI 2021).

Life Form	Scientific Name	Common Name	Nativity	Wetland Status [1]	Endemic
Forbs/Herbs	*Asclepias speciosa*	Showy milkweed	Native	FAC	No
	Cirsium vulgare	Bull thistle	Non-native	FACU	No
	Equisetum arvense	Field horsetail	Native	FAC	No
	Halogeton sp.	Saltlover	Non-native	UPL	No
	Navarretia squarrosa	Skunkbush	Native	FACU	No
	Oenothera elata	Hooker's evening primrose	Native	FACW	No
	Oenothera longissima	Longstem evening primrose	Native	OBL	No
	Orobanchaceae sp.	Broomrape	Unknown	Unknown	No
	Plantago patagonica	Woolly plantain	Native	UPL	No
	Salsola kali	Russian thistle	Non-native	UPL	No
	Typha sp.	Cattail	Unknown	Unknown	No
	Wyethia sp.	Mule's ears	Unknown	Unknown	No
	Yucca angustissima	Narrowleaf yucca	Native	UPL	No
	Gutierrezia sarothrae	Broom snakeweed	Native	UPL	No

[1] OBL (obligate wetland) = almost always occurs in wetlands; FACW (facultative wetland) = usually occurs in wetlands but occasionally found in uplands; FAC (facultative) = occurs in either wetlands or uplands: FACU (facultative upland) = sometimes occurs in wetlands but usually occurs in uplands; UPL (upland) = almost always occurs in uplands.

Appendix D. Disturbances and Characteristics of Rare Plant Habitat

Table D-1 summarizes the primary disturbances and characteristics for CARE's rare plant species.

Table D-1. Summary of primary disturbances and characteristics defining potential habitat for rare plant species in CARE.

Group	Common Name	Primary Disturbance	Primary Geological Formation	Elevation Range	Primary Plant Community
Threatened (T) & Endangered (E)	Barneby reed-mustard (E) [1]	Unknown (2 sites listed as none)	Moenkopi	1,717–2,026 m (5,633–6,647 ft)	*Pinus edulis - Juniperus osteosperma* / (*Shepherdia rotundifolia, Amelanchier utahensis*) Woodland
	Jones cycladenia (T) [1]	Livestock, bighorn sheep, human	Chinle	2,011–2,040 m (6,631–6,631 ft)	*Pinus edulis - Juniperus osteosperma / Shepherdia rotundifolia* Woodland [Provisional]; *Pinus edulis - Juniperus osteosperma* / Xeric Shrubs Woodland Complex
	Last Chance townsendia (T) [1]	Livestock and light native ungulate use	Morrison, Carmel, Summerville	1,835–2,695 m (6,020–8,842 ft)	*Pinus edulis - Juniperus osteosperma / Ephedra torreyana - Artemisia bigelovii* Woodland; *Pinus edulis - Juniperus osteosperma / Shepherdia rotundifolia* Woodland [Provisional]
	Ute ladies-tresses (T) [2]	Unknown	Alluvium	1,310–2,134 m (4,298–7,001 ft)	Forested wetland, scrub-shrub wetland, bog/fen, riparian, herbaceous wetland
	Wright fishhook cactus (E) [1]	Livestock and native ungulate use	Entrada Sandstone	1,517–2,042 m (4,977–6,699 ft)	*Atriplex confertifolia* Shrubland Complex; *Ephedra torreyana / Bouteloua gracilis* Shrubland
	Winkler cactus (T) [1]	Livestock and some native ungulate trampling	Morrison	1,681–2,125 m (5,515–6,972 ft)	*Pinus edulis - Juniperus osteosperma* / Xeric Shrubs Woodland Complex and multiple other pinyon pine – juniper communities

[1] CARE rare plants Access database.

[2] NatureServe (2021).

[3] USDA and USDOI (2006

Table D-1 (continued). Summary of primary disturbances and characteristics defining potential habitat for rare plant species in CARE.

Group	Common Name	Primary Disturbance	Primary Geological Formation	Elevation Range	Primary Plant Community
NPS Sensitive Species	Abajo daisy [2]	Unknown	Limestone and igneous substrates, clay loam	2,100–3,400 m (6,890–11,155 ft)	Forest - Conifer, Forest/Woodland, Woodland – Conifer (*Pinus edulis - Juniperus osteosperma*)
	Alcove bog-orchid [1]	Unknown	Navajo Sandstone and Kayenta	1,204–1,951 m (3,950–6,401 ft)	Hanging gardens, springs, seeps (incomplete information)
	Bicknell milkvetch [2]	Unknown	Unknown	1,825–2,600 m (5,988–8,530 ft)	*Artemisia* spp.-grassland and *Pinus edulis - Juniperus osteosperma* communities
	Bolander's camissonia [2]	Unknown	Moenkopi	1,457 m (4,780 ft)	Unknown but found in association with *Atriplex* sp. and *Ephedra* sp.
	Cataract gilia [1]	Unknown	Unknown	1,160–1,590 m (3,806–5,217 ft)	Shadscale and other mixed desert scrub
	Harrison's milkvetch [1]	Hiking, vehicles, livestock	Navajo Sandstone, Kayenta	1,646–1,898 m (5,400–6,227 ft)	*Pinus edulis - Juniperus osteosperma / (Shepherdia rotundifolia, Amelanchier utahensis)* Woodland; *Pinus edulis - Juniperus osteosperma / Cercocarpus intricatus* Woodland and other *Pinus edulis-Juniperus osteosperma* communities
	Henrieville woody-aster [1]	Unknown	Kaiparowits, Morrison, Moenkopi	1,400–2,200 m (4,953–7,218 ft)	*Pinus edulis - Juniperus osteosperma* communities on barren, often alkaline, clay soils

[1] CARE rare plants Access database.

[2] NatureServe (2021).

[3] USDA and USDOI (2006

Table D-1 (continued). Summary of primary disturbances and characteristics defining potential habitat for rare plant species in CARE.

Group	Common Name	Primary Disturbance	Primary Geological Formation	Elevation Range	Primary Plant Community
NPS Sensitive Species (continued)	Maguire daisy [1]	None at most sites, but a few are subject to human disturbance	Navajo Sandstone	1,585–2,463 m (5,200–8,081 ft)	*Cercocarpus intricatus* Slickrock Sparse Vegetation; *Pinus edulis - Juniperus osteosperma / (Shepherdia rotundifolia, Amelanchier utahensis*) Woodland; *Pinus edulis - Juniperus osteosperma / Cercocarpus intricatus* Woodland
	Mussentuchit gilia [2,3]	Unknown	Carmel, Dakota, Curtis, Summerville, Entrada, Navajo Sandstone	1,524–2,134 m (5,000–7,000 ft)	*Pinus edulis – Juniperus osteosperma/ Amelanchier utahensis woodland, Pinus edulis – Juniperus osteosperma/ Cercocarpus intricatus; and Chrysothamnus nauseosus*
	Osterhout's cryptanth [2]	Unknown	Sandstone	1,370–2,000 m (4,495–6,562 ft)	Forest/Woodland, Desert, Shrubland/chaparral, Woodland - Conifer
	Pinnate spring-parsley [1]	Hikers	Navajo Sandstone, Kayenta	2,396–1,738 m (7,861–5,702 ft)	*Cercocarpus intricatus* Slickrock Sparse Vegetation
	Rabbit Valley gilia [2]	Unknown	Navajo, Wingate, Carmel	1,554–2,743 m (5,098–8,999 ft)	Bare rock/talus/scree, Forest/Woodland, Woodland - Conifer, Shrubland/chaparral
	San Rafael phacelia [2]	Unknown	Carmel, Chinle, Summerville, and Moenkopi	1,065–1,830 m (3,494–6,004 ft)	*Atriplex confertifolia* Shrubland Complex; *Pinus edulis - Juniperus osteosperma* communities
	Welsh's aster [2]	Unknown	Navajo, Kayenta	1,300–2,440 m (4,265–8,005 ft)	Bare rock/talus/scree at the margins of springs, wet meadows, and along stream banks.

[1] CARE rare plants Access database.

[2] NatureServe (2021).

[3] USDA and USDOI (2006

Table D-1 (continued). Summary of primary disturbances and characteristics defining potential habitat for rare plant species in CARE.

Group	Common Name	Primary Disturbance	Primary Geological Formation	Elevation Range	Primary Plant Community
Former NPS Sensitive Species	Alpine greenthread [1,2]	None or Not Reported	Carmel	2,100–2,745 m (6,890–9,006 ft)	*Pinus edulis Juniperus osteosperma*, mountain brush, and western bristlecone pine communities
	Heil's wild buckwheat [1]	None	Carmel	2,499–2,960 m (8,199–9,711 ft)	*Pinus longaeva* Woodland; *Pinus edulis - Juniperus osteosperma*/ Cushion Plant Woodland
	Johnson's cryptanth [1,2]	Grazing	Entrada, Carmel	1,800–1,950 m (5,906–6,398 ft)	Sparsely vegetated mixed desert shrub, shadscale barrens and *Pinus edulis - Juniperus osteosperma* communities
	Low hymenoxys [1]	Not Reported for most sites; No disturbance at 3 sites	Navajo Sandstone, Carmel	1,939–2,610 m (6,362–8,856 ft)	*Cercocarpus intricatus* Slickrock Sparse Vegetation; *Pinus edulis - Juniperus osteosperma* communities
	Rush Lomatium [1]	No disturbance reported at 4 of 6 sites	Chinle, Moenkopi	1,691–2,024 m (5,548–6,640 ft)	*Pinus edulis - Juniperus osteosperma / (Shepherdia rotundifolia, Amelanchier utahensis)* Woodland; *Ephedra torreyana - Artemisia bigelovii* Sparse Vegetation
	Woodside wild buckwheat [2]	None reported (only 1 site)	Carmel	1,982 m (6,503 ft)	*Pinus edulis-Juniperus osteosperma*/ Cushion Plant Woodland

[1] CARE rare plants Access database.

[2] NatureServe (2021).

[3] USDA and USDOI (2006)

The Department of the Interior protects and manages the nation’s natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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